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Draft Work Plan for a Treatability Study in Support of the Intrinsic Remediation (Natural Attenuation) Option at Sites OT-41 and SS-42

Wurtsmith Air Force Base
Oscoda, Michigan

Prepared For

Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas

and

Wurthsmith Air Force Base
Oscoda, Michigan

February 1995

PARSONS
ENGINEERING SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado 80290

AQ M01-04-0718

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WORK PLAN FOR A TREATABILITY STUDY IN SUPPORT OF THE INTRINSIC REMEDIATION (NATURAL ATTENUATION) OPTION AT SITES OT-41 AND SS-42

at

WURTSMITH AIR FORCE BASE
OSCODA, MICHIGAN

February 1995

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

AND

WURTSMITH AIR FORCE BASE
OSCODA, MICHIGAN

Prepared by:

Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

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SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering-Science, Inc. (ES), presents the scope of work required for the collection of data necessary to develop a treatability study (TS). The TS will address remediation of ground water contaminated with petroleum hydrocarbons at Sites OT-41 and SS-42 (near Building 5009) at Wurtsmith Air Force Base (Base), in Oscoda, Michigan. This work plan is oriented toward the collection of hydrogeologic and chemical data that will be used to document the occurrence of intrinsic remediation of benzene, toluene, ethylbenzene, and xylenes (BTEX) dissolved in ground water. Intrinsic remediation is a risk management strategy that relies on natural attenuation to control the risks associated with exposure to contaminants in the subsurface. However, data collected under this program will also allow for the evaluation of several remedial options, such as free product removal; bioventing for source removal; air sparging; and intrinsic remediation with long-term monitoring (LTM).

This work plan was developed based on discussions among representatives from the Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division, Michigan Department of Natural Resources (MDNR), Wurtsmith AFB, and Parsons ES at a meeting at the Base on August 24, 1994; on the statement of work (SOW) for this project; and on a review of existing site characterization data. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993) and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and Wurtsmith AFB.

1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide a TS for remediation of ground water contamination at Sites OT-41 and SS-42. However, this project is part of a larger, broad-based initiative being conducted by AFCEE, in conjunction with the US Environmental Protection Agency (USEPA) and Parsons ES, to document the biodegradation and resulting attenuation of fuel hydrocarbons dissolved in ground water, and to model this degradation using the Bioplume II numerical ground water model. For this reason, the work described in this work plan is directed toward the collection of data in support of this initiative. All data required to develop a 30-percent design of an alternate remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, also will be collected under this program. This work plan describes the site characterization activities to be performed under this program.

Proposed site characterization activities include: 1) determination of preferential contaminant migration pathways; 2) cone penetrometer and laser-induced fluorescence testing; 3) ground water monitoring point placement; 4) soil and ground water sampling; and 5) aquifer testing. The materials and methodologies required for collection of these data are described herein. Existing site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the Bioplume II model. Where site-specific data are not available, conservative values obtained from widely accepted published literature will be used for model input. Sensitivity analyses will be conducted for the parameters which are known to have the greatest influence on the results of Bioplume II modeling, and where possible, the model will be calibrated using historical site data. Upon completion of the Bioplume II modeling, Parsons ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not the most appropriate remedial option, Parsons ES will recommend the most appropriate ground water remedial technology on the basis of available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of existing site-specific data and a conceptual model for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and TS report format. Section 5 describes the quality

assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. There is one appendix to this work plan. Appendix A contains a listing of containers, preservatives, packaging, and shipping requirements for soil and ground water samples.

1.2 SITE BACKGROUND

The Base is located in the northeastern part of Michigan's Lower Peninsula, at approximately 44° 28' North and 83° 22' West. The Base occupies 4,626 acres withined within Township 24 North, Range 9 East in Iosco County, Michigan and is adjacent to the communities of Oscoda and Au Sable on the western shore of Lake Huron (Figure 1.1). Sites OT-41 and SS-42 are in Operable Unit (OU) 4 and are located near Building 5009 in the central section of the Base, approximately 3,000 feet southeast of the northeastern end of the southwest-northeast runway (Figure 1.2).

Site OT-41 is at the Aerospace Ground Equipment (AGE) refueling island (Facility 5011), near Building 5009. Three 2,000-gallon underground storage tanks (USTs) containing JP-4 (jet fuel), MOGAS (gasoline), and diesel fuel were located at the facility. The JP-4 tank passed a tank-tightness test (Tracer Tight® test method). A small, intermittent leak of unknown quantity was identified near the Mogas tank during testing. The results for the diesel tank were inconclusive. The tanks have been removed, and the resulting excavation has been backfilled with native sand.

The Installation Restoration Program (IRP) process was formally initiated at the Base in 1984. The IRP Phase I records search was performed by Radian Corporation (1985). The US Geologic Survey (USGS, 1990b and 1991) performed IRP Phase II confirmation/quantification work in two stages.

Previous investigations at Site OT-41 have included the installation of soil gas sampling probes at five locations; the removal of the tanks and collection of soil samples from each of the three tank excavations in July 1991; and the installation and sampling of three downgradient wells and the collection of soil samples from nine soil borings around the MOGAS tank by the United States Geological Survey (USGS) in March 1992 (ICF, 1993).

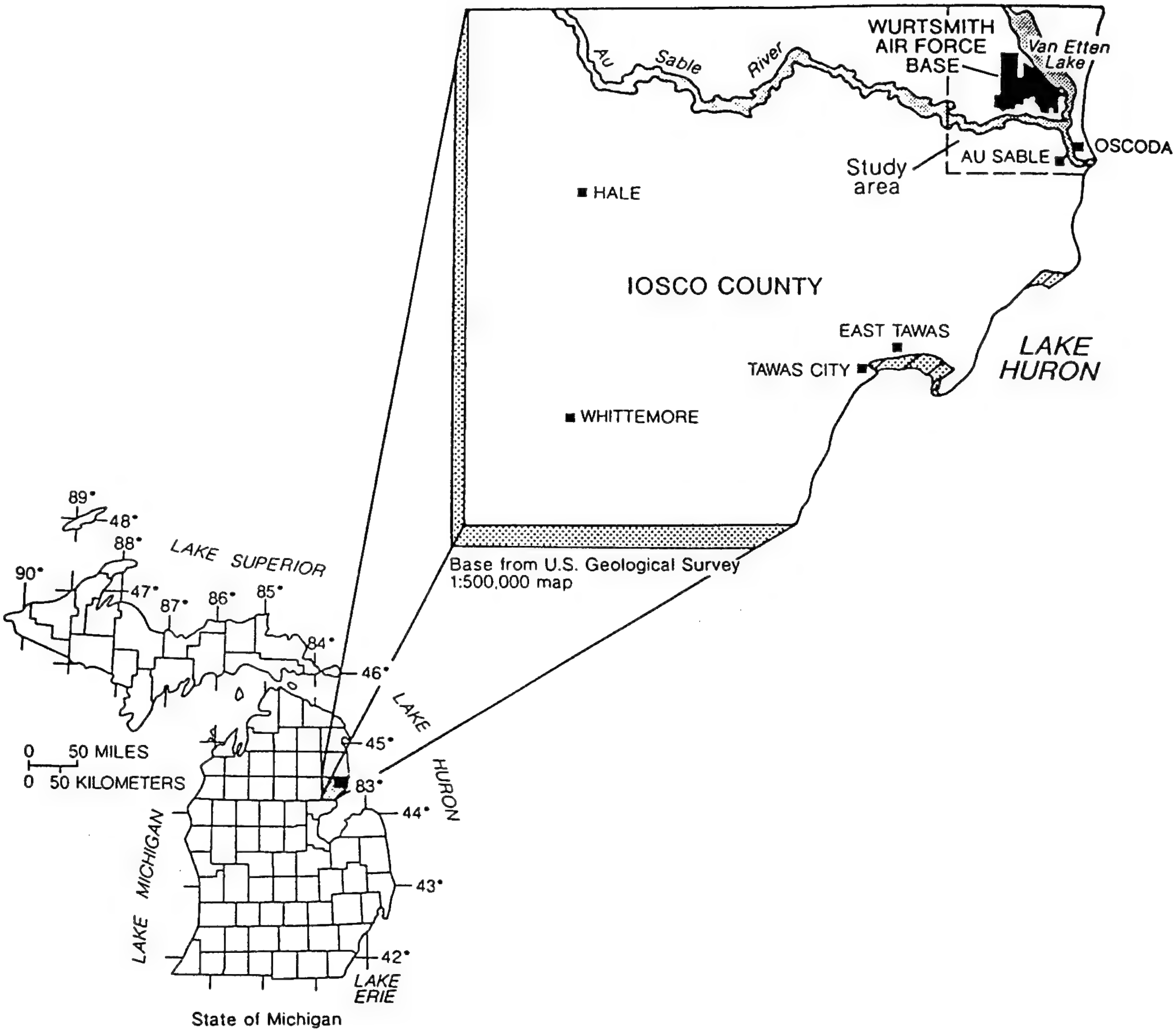

FIGURE 1.1

REGIONAL LOCATION MAP

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

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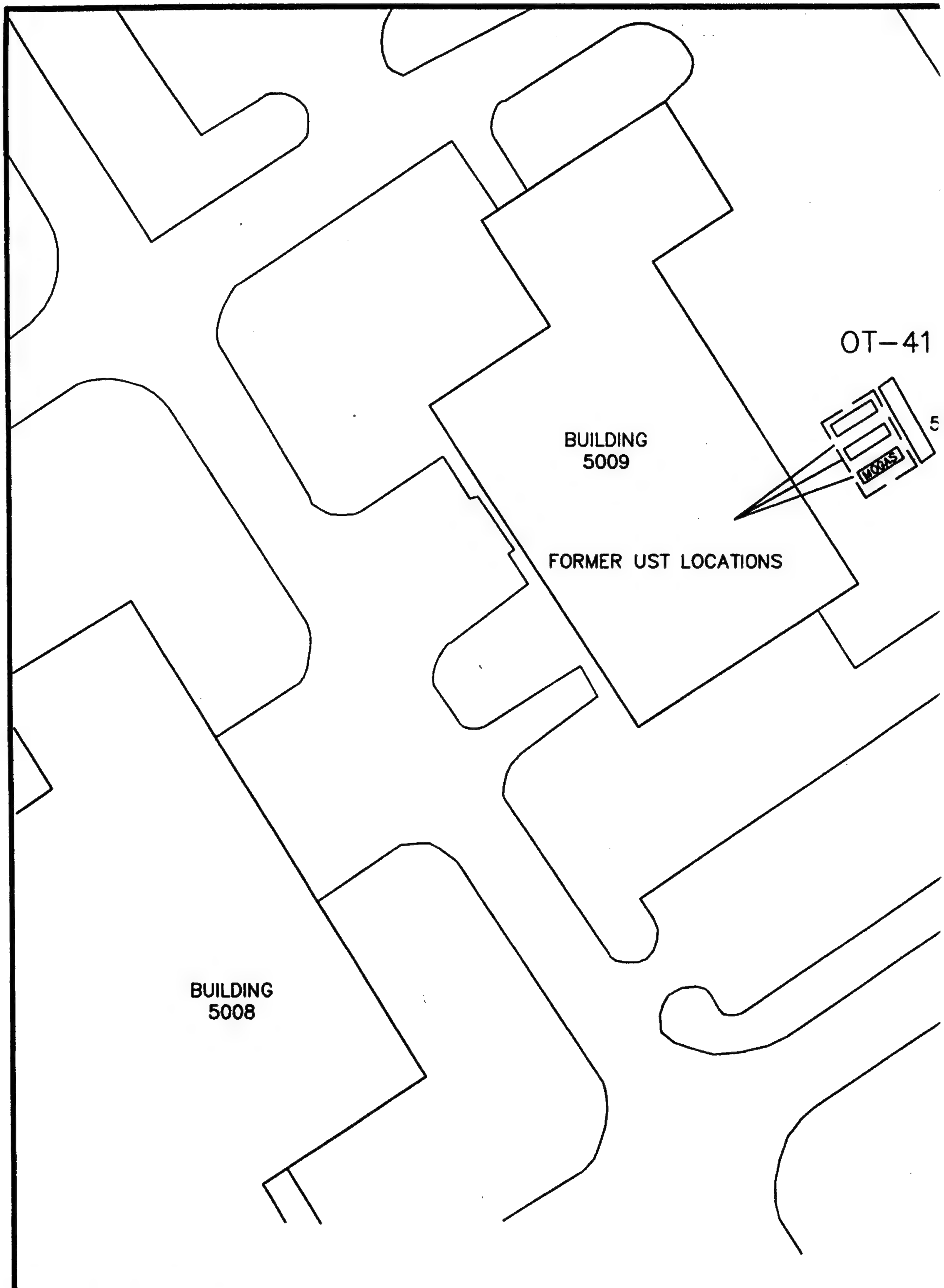

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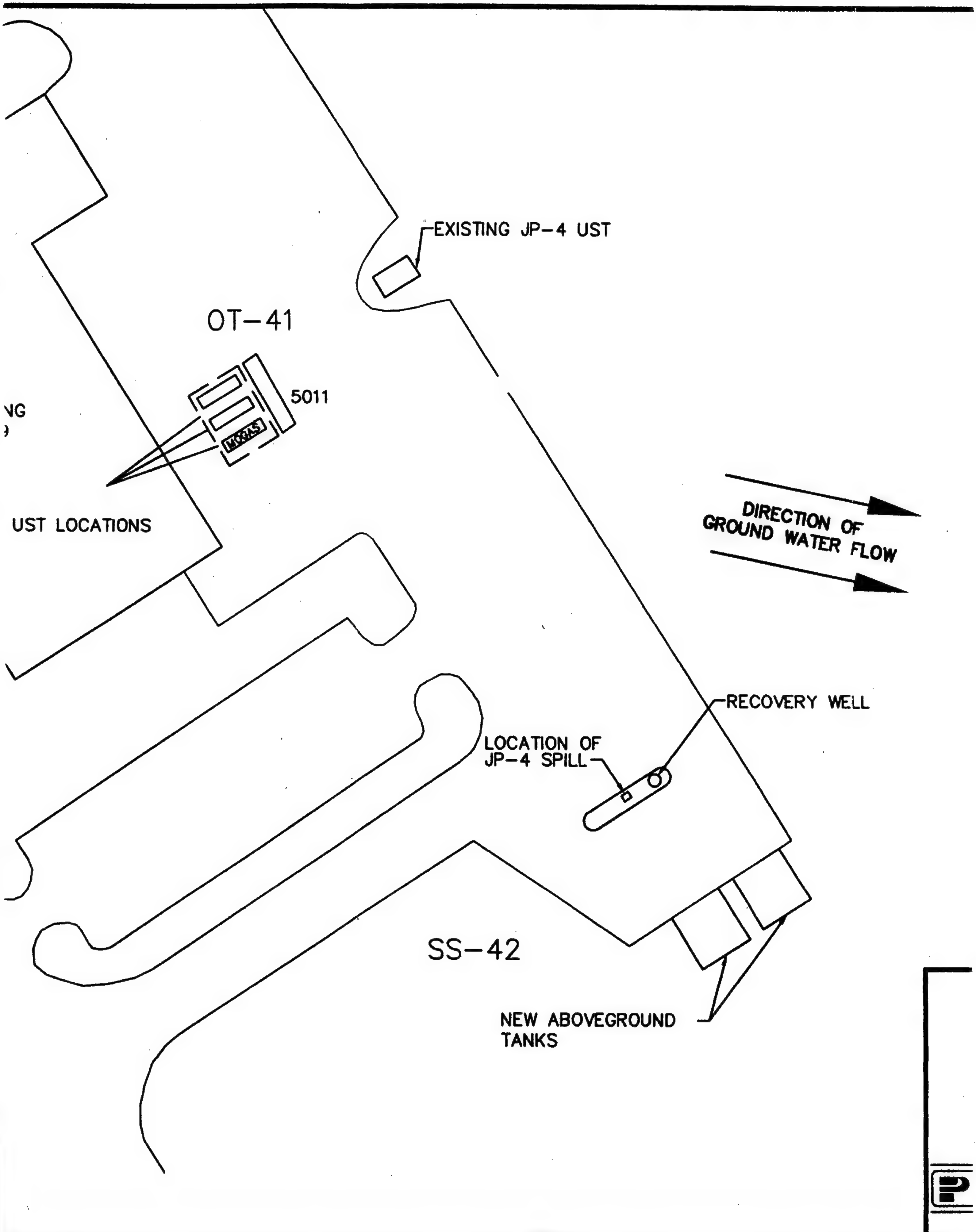
EXISTING JP-4 UST
OT-41
5011
MOGAS
NG
UST LOCATIONS
DIRECTION OF GROUND WATER FLOW
RECOVERY WELL
LOCATION OF JP-4 SPILL
SS-42
NEW ABOVEGROUND TANKS

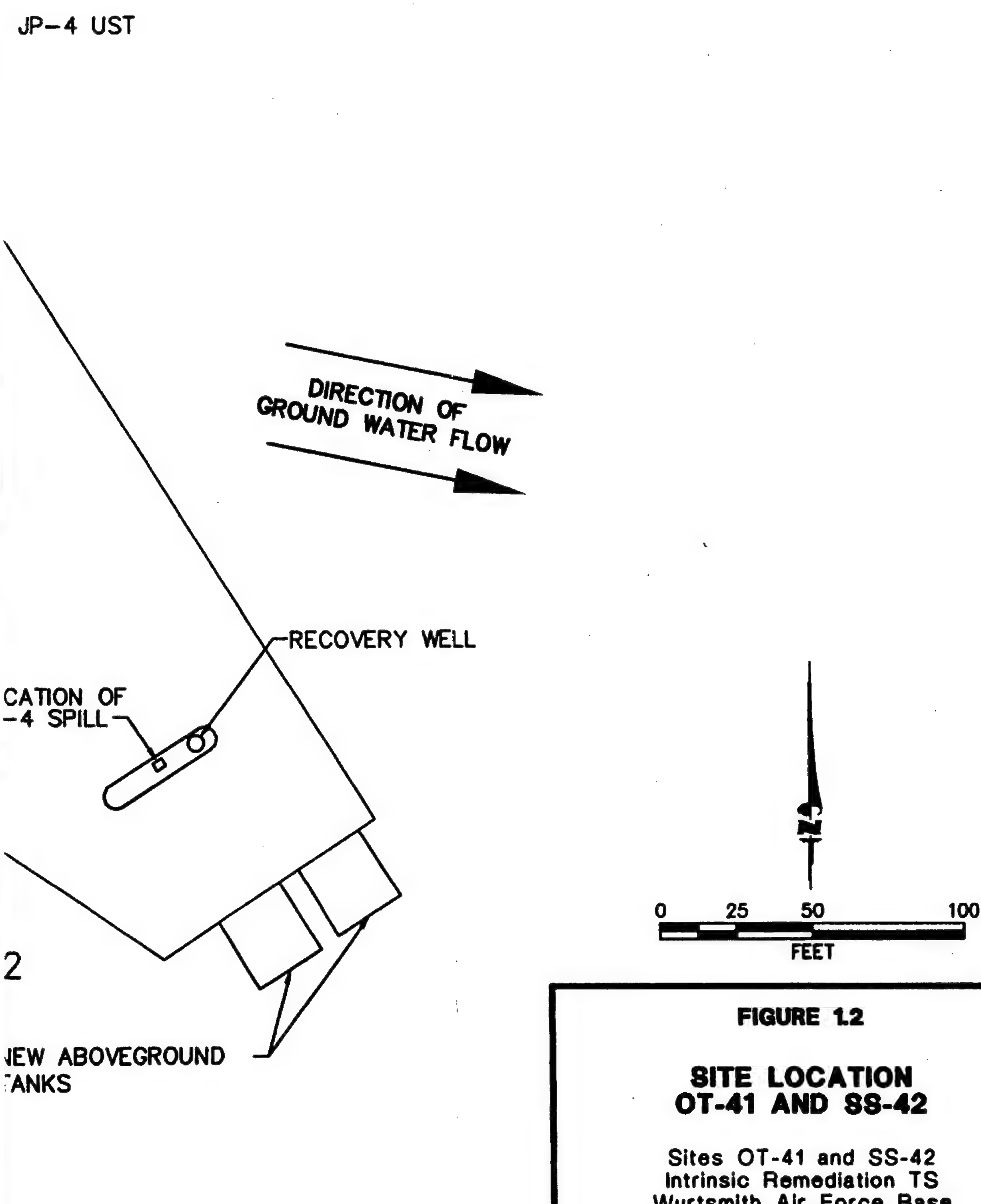

FIGURE 1.2

SITE LOCATION
OT-41 AND SS-42

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

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Site SS-42, also at the AGE facility near Building 5009, is the site of an aboveground storage tank (AST) that contained JP-4. In November 1991, a malfunctioning fuel pump siphoned approximately 1,400 gallons of fuel into the ground beneath the pump. Approximately 100 gallons of MOGAS also may have leaked into the ground from a nearby pump.

Previous investigations at Site SS-42 have included the installation of two monitoring wells, the collection of soil samples for analysis, and the discovery of free product in November 1991; installation of auto-skimming equipment in a recovery well, and the recovery of 750 gallons of product by June 1992 (ICF, 1993).

An IRP remedial investigation (RI) was initiated at the Base in 1992 by ICF Technology, Inc. (ICF) and resulted in the preparation of a draft RI report in April 1993, completed in accordance with the National Contingency Plan, Michigan Act 307, and related Michigan Department of Natural Resources (MDNR) guidance (ICF, 1993). The RI work consisted of the collection of 55 soil gas samples at OT-41 and SS-42 to assist in identifying the extent of contamination and to assist in the placement of soil boring and monitoring well locations. Ten soil borings were installed to depths of nearly 20 feet below ground surface (bgs), and soil samples were collected for analysis. Three monitoring wells (MW1-OT41, MW1-SS42, and MW2-SS42) were installed and samples were collected for soil and ground water analysis. A draft feasibility study (FS) was initiated in 1993 (ICF, 1994).

Results of the RI indicated the presence of dissolved-phase fuel hydrocarbons in the ground water at the site of the removed USTs (OT-41) and beneath and downgradient of the JP-4 spill site (SS-42). The site-specific data and conceptual model presented in Section 2 are based on a review of the RI/FS documents.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

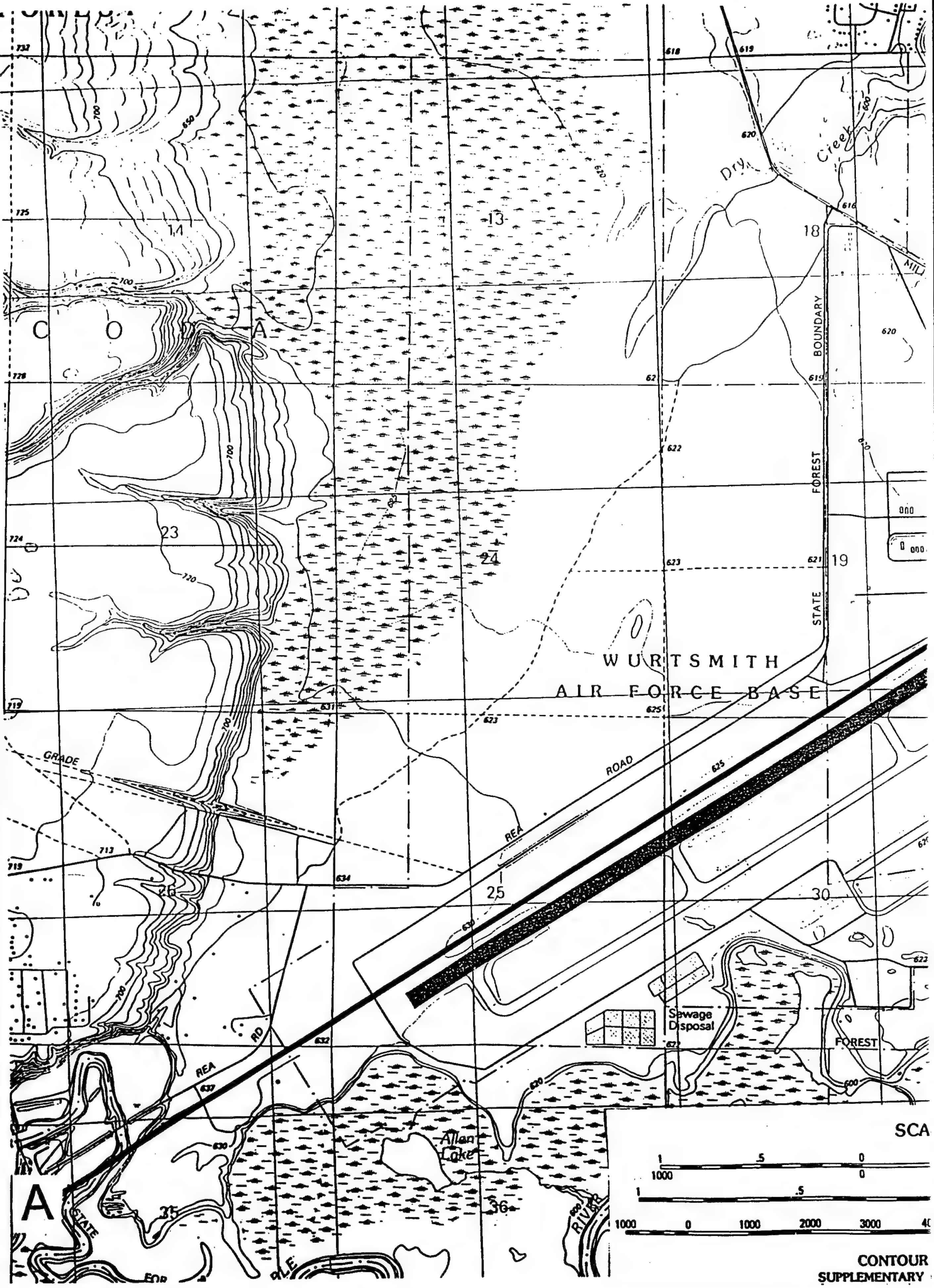
Existing site-specific data were reviewed and used to develop a conceptual model for round water flow and contaminant transport in the area near Building 5009. This conceptual model will allow efficient collection of additional data that will be used to support the Bioplume II modeling effort and to evaluate potential remediation technologies, including intrinsic remediation. Sections 2.1 and 2.2 present a synopsis of available site data. Section 2.3 presents the preliminary conceptual ground water flow and solute transport model which was developed based on these data.

2.1 DATA REVIEW

The following sections were based upon the review of data provided by Wurtsmith AFB and from the draft RI report (ICF, 1993), preliminary final environmental impact statement (Earth Technology Corporation, 1993), and the draft FS report (ICF, 1994).

2.1.1 Topography, Surface Hydrology, and Climate

Wurtsmith AFB is located within a nearly level coastal sand plain of the Eastern Lake section of the Central Lowland Physiographic Province. The Base is located on a 5-mile-wide sandy plain that is part of the Oscoda Lake plain. This plain extends from Lake Huron in the east to 80-foot-high bluffs (remnants of Pleistocene deltaic deposits) west of the Base (USGS, 1990a). Elevation varies from 580 feet above mean sea level (MSL) at the Lake Huron shoreline east of the Base, to about 650 feet MSL at the base of the bluff, and to 730 feet MSL at the top of the bluffs to the west of the Base. The topography of the Base is flat to gently rolling, interrupted by several long, linear ridges that are geomorphic expressions of ancient beaches and sand dunes (Figure 2.1).



Source: USGS, 1989.

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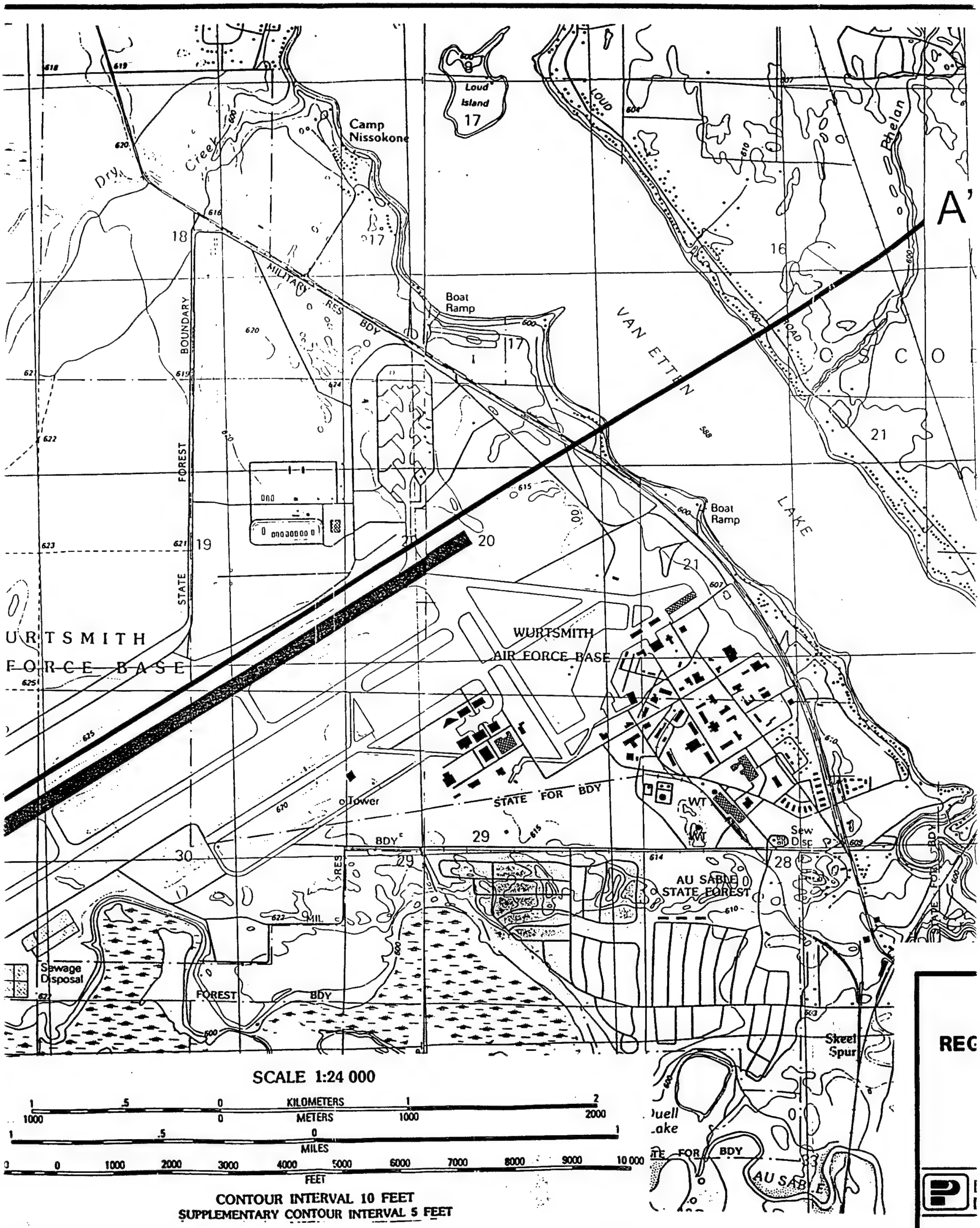
Camp Nissokone
Loud Island
Dry Creek
A'
MILITARY RES BDY
BOUNDARY
FOREST
STATE
Boat Ramp
VAN ETTEN LAKE
LOUD ROAD
Phelan
WURTSMITH AIR FORCE BASE
STATE FOR BDY
Tower
WT
Sew Disp
AU SABLE STATE FOREST
Sewage Disposal
FOREST BDY
MIL RES BDY
Skeel Spur
Duell Lake
AU SABLE
REG
SCALE 1:24 000
KILOMETERS
METERS
MILES
FEET
CONTOUR INTERVAL 10 FEET
SUPPLEMENTARY CONTOUR INTERVAL 5 FEET

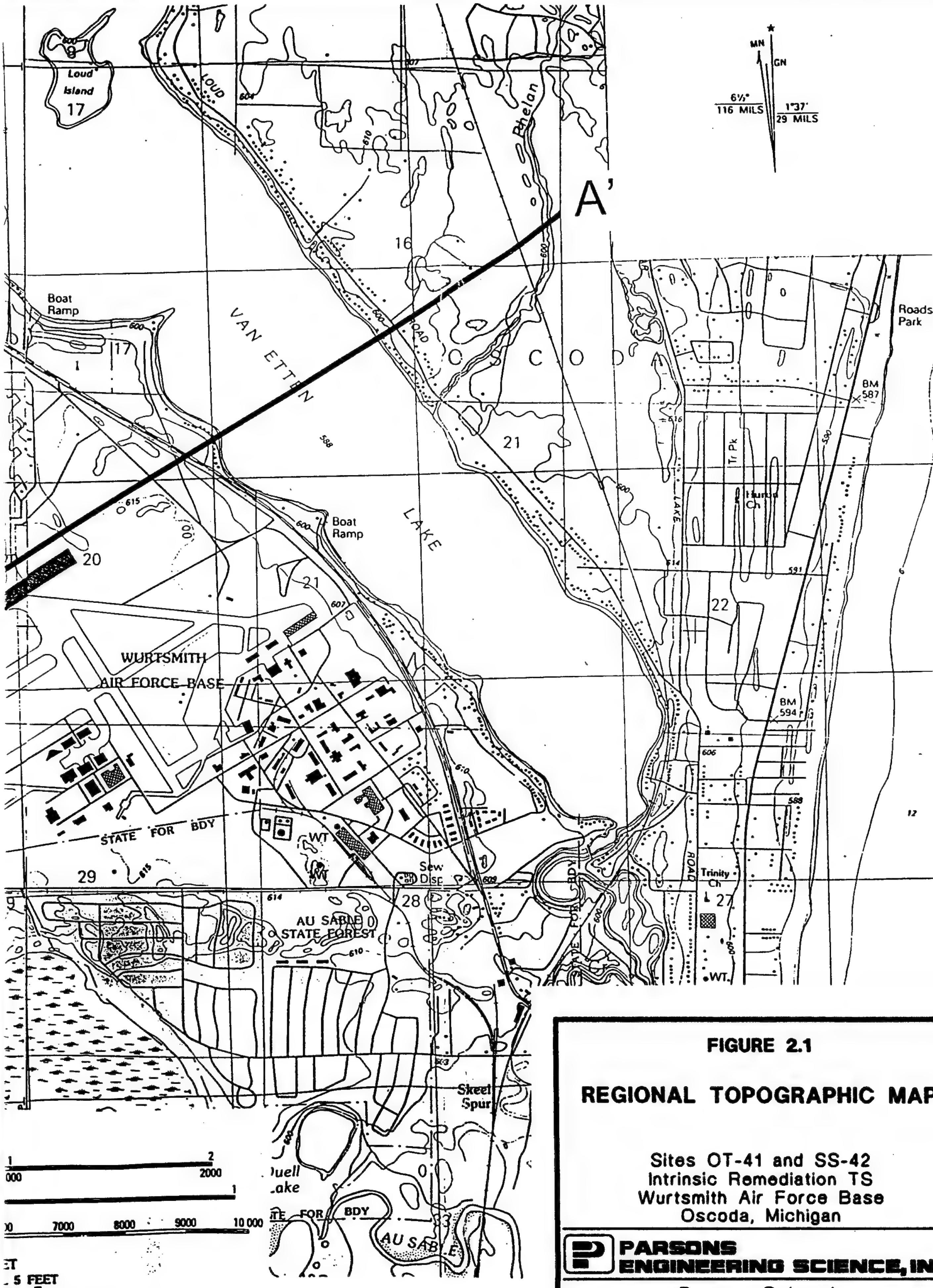

FIGURE 2.1

REGIONAL TOPOGRAPHIC MAP

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

The annual precipitation averages 30.4 inches, with the highest precipitation rates occurring in the spring and summer months. According to meteorological data collected at the Base, the highest average monthly precipitation normally occurs in June (3.1 inches), and the lowest average monthly precipitation normally occurs in January (1.6 inches). The mean monthly air temperature ranges from 21 degrees Fahrenheit (^{o}F) in January to 69 ^{o}F in July.

The Au Sable River is located approximately 1 mile south of the Base and flows in an easterly direction to Lake Huron. Van Etten Lake, a man-made lake 4 miles long and 0.5 mile wide, is located adjacent to the eastern and northeastern perimeter of the Base. Van Etten Lake is fed by the Pine River to the north and discharges into the Van Etten Creek to the south. The Van Etten Creek is a tributary to the Au Sable River. Wetland areas are located at the foot of the bluff along the western edge of the Base and along the southwestern border of the Base. Ground water on the Base eventually flows into Van Etten Lake or Van Etten Creek.

2.1.2 Overview of Geology and Hydrogeology

2.1.2.1 Local Geology and Hydrogeology

The surface soils on the Base are included in the Grayling Complex soils association. These soils include sand, silt, and a small amount of clay. The soils are a result of the weathering of Quaternary glacial outwash deposits and recent aeolian action. The soils are highly permeable and are classified as excessively drained, thus allowing rapid infiltration of precipitation.

The geologic units at the Base consist of approximately 100 to 250 feet of unconsolidated glacial deposits underlain by Mississippian sandstone and shale. From the surface, the unconsolidated glacial deposits consist of approximately 70 feet of beach, aeolian, and alluvial sand and gravel deposits; 40 to 110 feet of lacustrine silt and clay; and 40 to 75 feet of glacial till resting unconformably on the erosional surface of the bedrock (Rama Rao & Alfred, 1992). The upper units of the bedrock consist of the Marshall Formation, a very fine- to coarse-grained sandstone containing layers of siltstone, shale, and sandy shale. The sandstones may be either hard or soft, depending upon cementing and/or weathering. Where cemented or hard, the Marshall Formation

sandstones are fractured. Beneath the Marshall Formation is the Coldwater Shale, which may be up to 1,300 feet thick, with thin layers of limestone, dolomite, sandstone, siltstone, and shale. Figure 2.2 shows the typical geologic and hydrogeologic units at the Base. Figure 2.3 is a geologic cross section illustrating the relationships between the geologic units found at the Base.

The upper unconsolidated glacial sands and gravels form the principal aquifer in the region. This aquifer is unconfined. The underlying lacustrine silt and clay layer acts as an aquitard, effectively separating the upper water-bearing zone from the water-bearing zone occurring in the underlying glacial deposits, and retarding or preventing downward migration of contaminants. The shallow water-bearing zone has an average saturated thickness of approximately 55 to 65 feet and is the principal water supply source for the base. The glacial deposits are recharged directly by precipitation and infiltration from the surface. Ground water in the hydrogeologic units beneath the silt and clay aquitard has high concentrations of dissolved solids or high chloride concentrations, rendering it undesirable as a drinking water source.

The depth to ground water at the Base is approximately 19 feet below ground surface (bgs). Water table elevations in the unconfined glacial deposits range from approximately 580 feet msl near Lake Huron to approximately 700 feet msl in the highlands west of the base. Annual fluctuations range from 1 to 3 feet. Figure 2.4 is a regional water table map, based on previous hydrogeologic investigations, that indicates the presence of a water table divide trending northwest-southeast across the base. South of the divide, ground water flows south toward the Au Sable River. North of the divide, ground water flows east to Van Etten Creek and Van Etten Lake.

ERA	PERIOD	EPOCH	GEOLOGIC UNIT	LITHOLOGY	HYDROGEOLOGIC UNIT
Cenozoic	Quaternary	Holocene	Eolian deposits	Sand	Sand and gravel water table aquifer 30–80 feet
			Beach deposits	Sand and gravel	
			Alluvium	Gravel, sand and silt	
		Pleistocene	Lacustrine (deltaic)	Sand and gravel	
			Lacustrine (clay)	Clay and silt	Silty-clay aquitard 100–250 feet
			Glacial till	Sand, gravel, silt, and clay	
					Lower sand and gravel aquifer 5–20 feet
Paleozoic	Mississippian	Osage	Marshall Fm.	Sandstone	Sandstone aquifer 0–50 feet
		Kinderhook	Coldwater Shale	Shale	Shale aquitard >500 feet

Source: ICF, 1993.

FIGURE 2.2

REGIONAL GEOLOGIC AND HYDROGEOLOGIC UNITS

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

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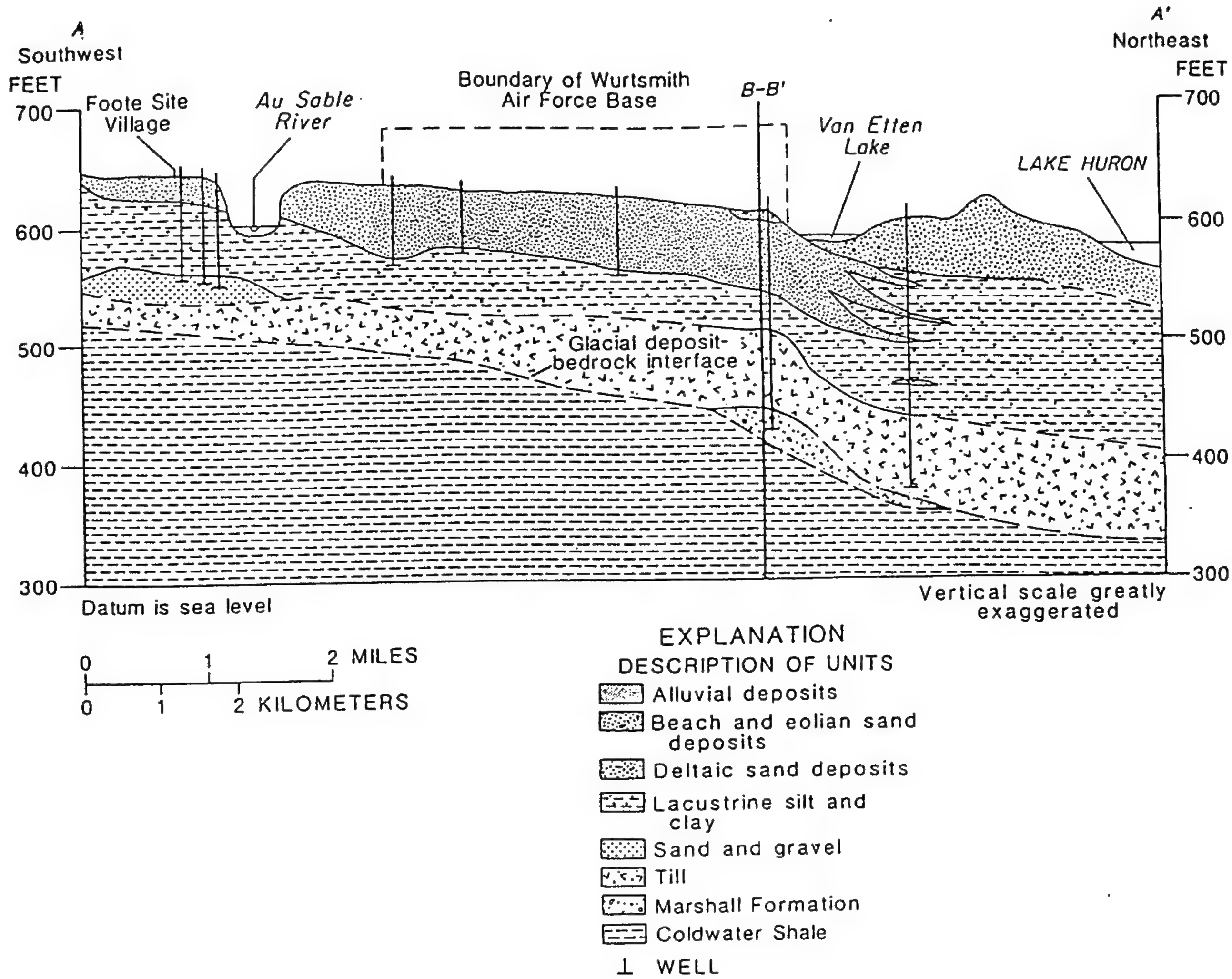

Source: USGS, 1990b.

FIGURE 2.3

BASE GEOLOGIC CROSS-SECTION

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

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Denver, Colorado

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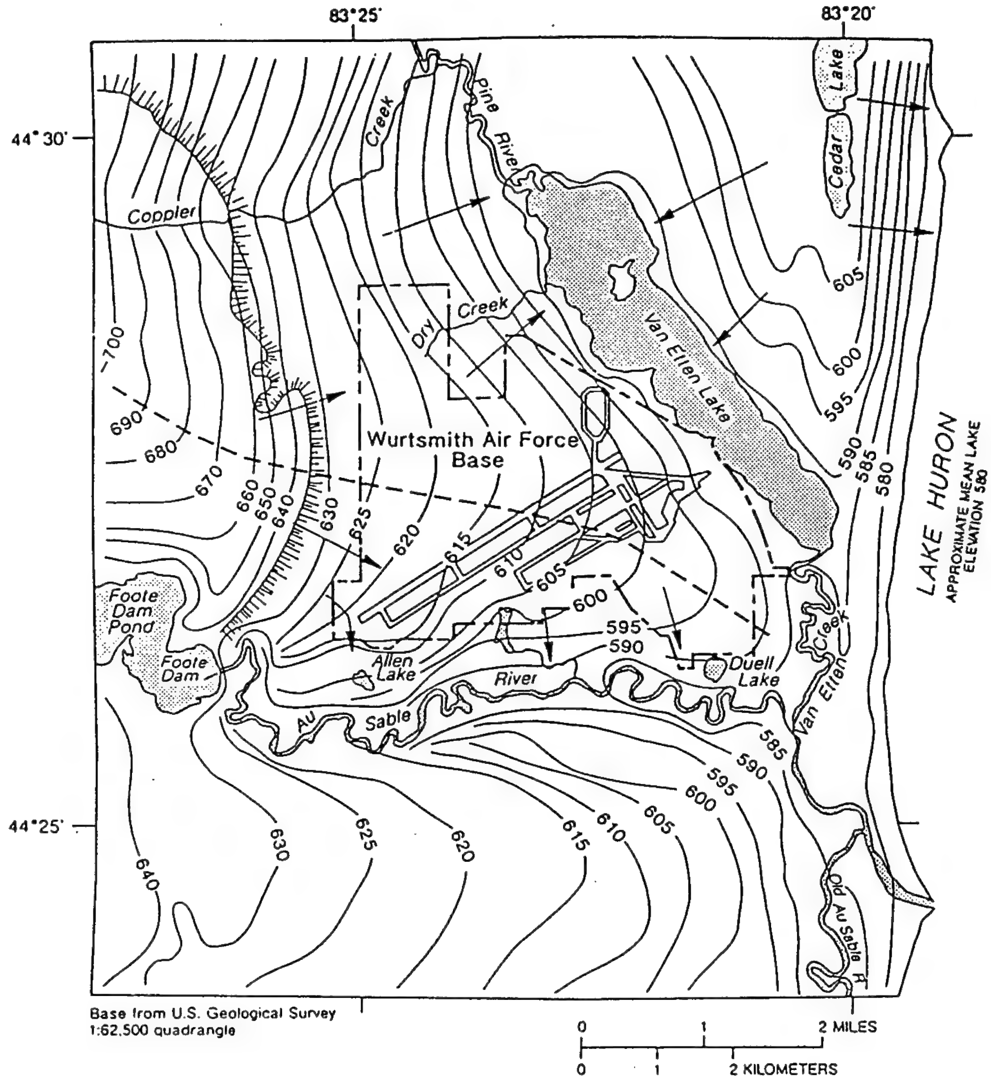

EXPLANATION

—600— WATER-TABLE CONTOUR--Shows elevation of water table. Contour interval 5 and 10 feet. Datum is sea level

- - - - GROUND-WATER DIVIDE

——► GROUND-WATER FLOW--Arrow indicates direction of flow

BLUFF

— - - — BOUNDARY OF WURTSMITH AIR FORCE BASE

FIGURE 2.4

BASE-WIDE WATER TABLE MAP

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

Source: USGS, 1990b.

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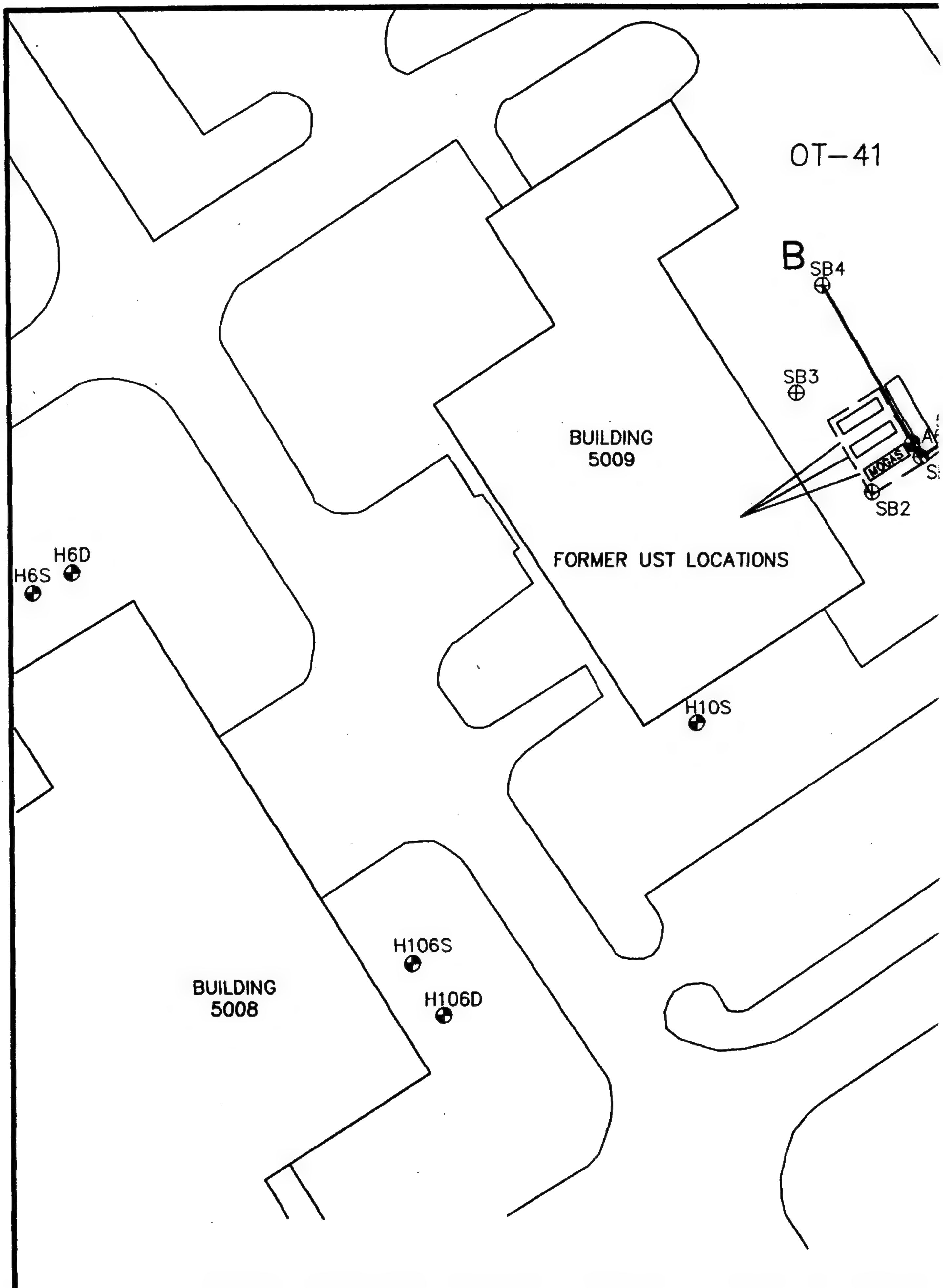
2.1.2.2 Site Geology and Hydrogeology

Figure 2.5 depicts the locations of soil borings and monitoring wells installed prior to, or during, the RI completed by ICF (1993), and the location of the generalized hydrogeologic cross section B-B'. Ten soil borings and three monitoring wells were completed during the RI. The soil borings were drilled to depths of nearly 20 feet and penetrated the upper portion of the unconsolidated glacial sediments. The shallow unconsolidated sediments consist of well sorted, light brown, medium-grained sands containing only a small amount of silt and clay-sized material. The sediments are relatively uniform, with only minor variations in grain size and no significant layers of fine-grained silts or clays (ICF, 1993). The three monitoring wells penetrated the entire thickness of the unconsolidated sands and gravels, to an average depth of 69 feet bgs. Thin lenses of coarse sand and gravel were encountered in the sediments 10 to 15 feet above the lacustrine clay layer. The clay layer is composed of relatively stiff, medium gray, silty clay (ICF, 1993).

Measurements taken during monitoring well installation indicated the depth to ground water ranges from approximately 18 feet bgs to approximately 22 feet bgs. Table 2.1 presents available well completion information, and Table 2.2 presents available ground water surface elevation measurements. Figure 2.6 is a water table elevation map prepared from data collected in March 1993, showing the ground water surface in the glacial deposits at Sites OT-41 and SS-42. Figure 2.7 is a generalized hydrogeologic section for the site. The approximate position of the water table is shown on the section to indicate the relationship between the geologic units at this site and the relative position of the water table. Ground water flow is generally to the east-southeast with a horizontal hydraulic gradient of 0.002 to 0.004 foot per foot (ft/ft). Water level measurements did not indicate a vertical gradient at the site. Although hydraulic conductivity was not determined from pump or slug tests during the RI, an estimate of 100 ft/day, obtained from previous studies (Stark *et al.*, 1983), was used to calculate the advective ground water velocity. A ground water velocity of 0.8 ft/day was calculated using the estimated hydraulic conductivity of 100 ft/day, an average porosity of 0.30, and a hydraulic gradient of 0.0024 as measured from the March 1993 water table map (ICF, 1993).



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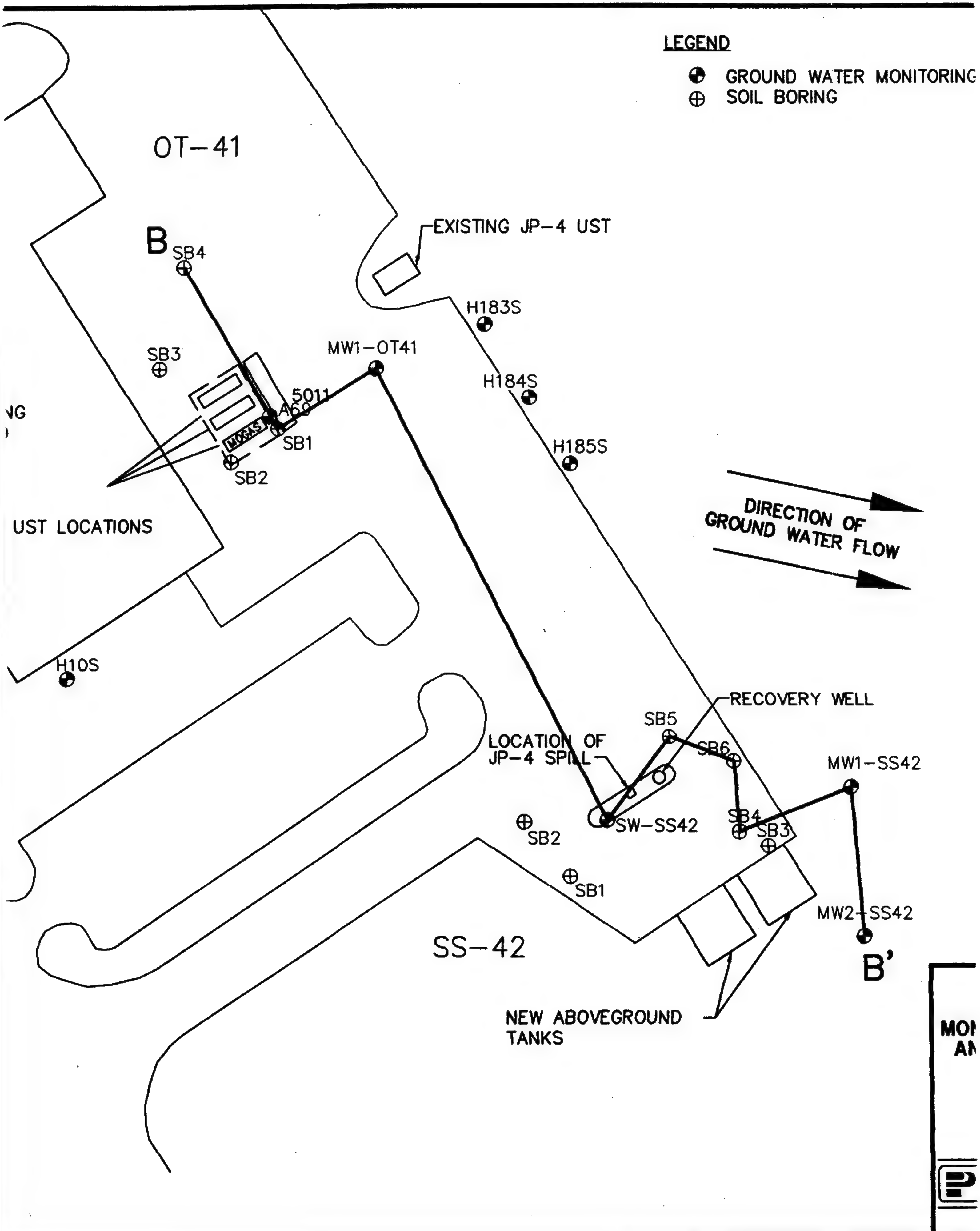
LEGEND
GROUND WATER MONITORING
SOIL BORING
OT-41
EXISTING JP-4 UST
B
SB4
H183S
SB3
MW1-OT41
H184S
5011
A69
MOGAS
SB1
SB2
H185S
UST LOCATIONS
DIRECTION OF GROUND WATER FLOW
H10S
RECOVERY WELL
SB5
LOCATION OF JP-4 SPILL
SB6
MW1-SS42
SB4
SW-SS42
SB3
SB2
SB1
MW2-SS42
SS-42
B'
NEW ABOVEGROUND TANKS

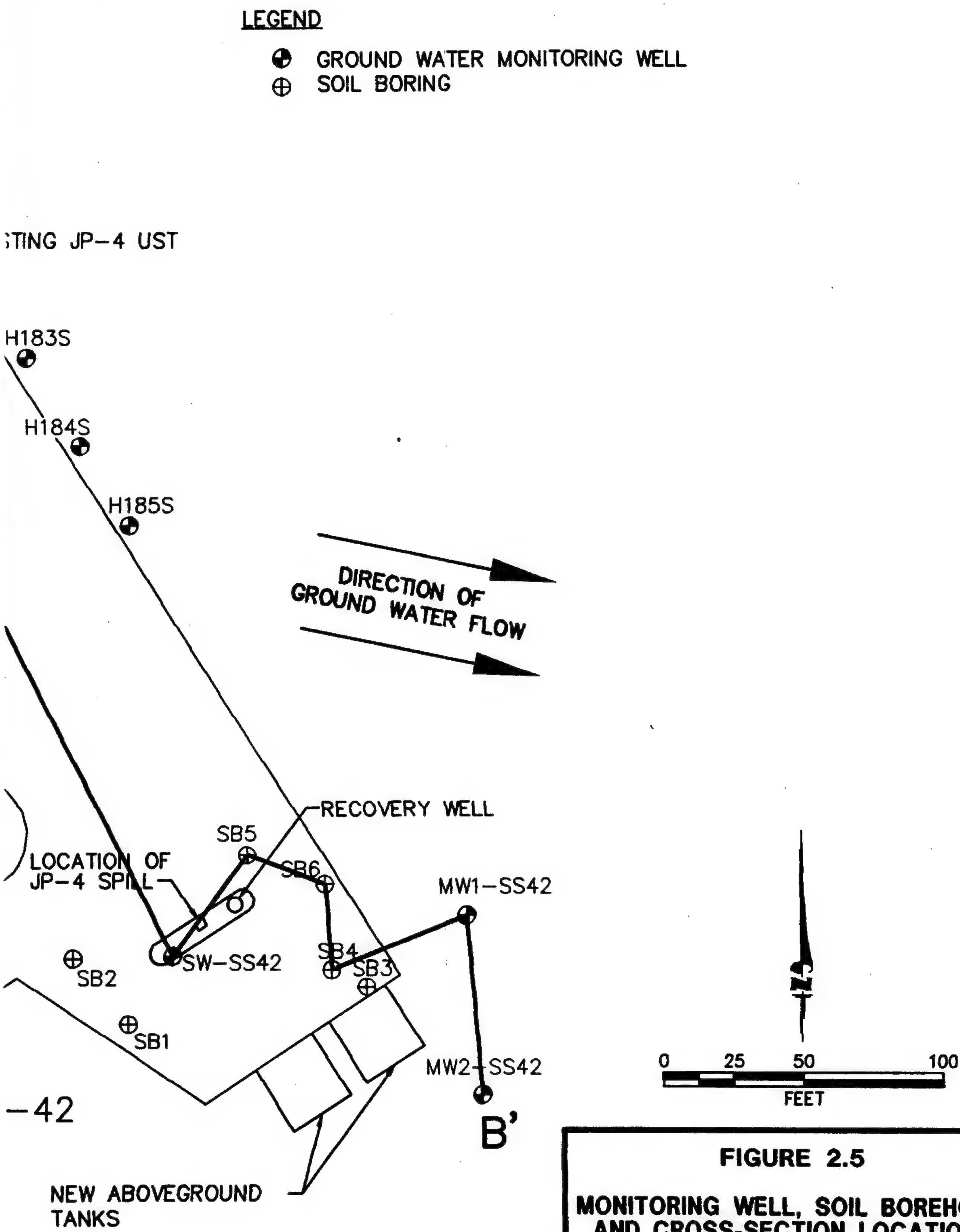

FIGURE 2.5

MONITORING WELL, SOIL BOREHOLE, AND CROSS-SECTION LOCATIONS

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

TABLE 2.1
MONITORING WELL CONSTRUCTION DETAILS
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Location	Well No.	Installation Date	Elevation, Top of Casing (ft. MSL)[a/]	Total Depth (ft. bgs)[b/]	Well Comp. Depth (ft. bgs)	Screen Interval (ft. bgs)	Screen Interval (ft. MSL)
OT-41	MW1-OT41	10/27/92	616.12	71.0	33	27.7-32.7	589-584
OT-41	A69	11/20/90	619.62	20.6	20.6	14.8-20.8	602-596
OT-41	H6S	2/1/81	620.81	28.2	NA	NA	595-591
OT-41	H10	3/1/81	619.78	28.0	NA	NA	622-618
OT-41	H183S	8/15/91	620.55	20.9	20.9	16.9-20.9	600-596
OT-41	H184S	8/15/91	620.49	21.1	21.1	16.8-20.8	600-596
OT-41	H185S	8/15/91	620.29	21.0	21.0	16.8-20.8	600-596
SS-42	MW1-SS42	11/4/92	619.33	70.0	23	13.2-23.2	603-593
SS-42	MW2-SS42	11/6/92	617.9	71.0	33	27.8-32.8	588-583

[a/] ft. MSL = Feet above mean sea level
[b/] ft. bgs = Feet below ground surface

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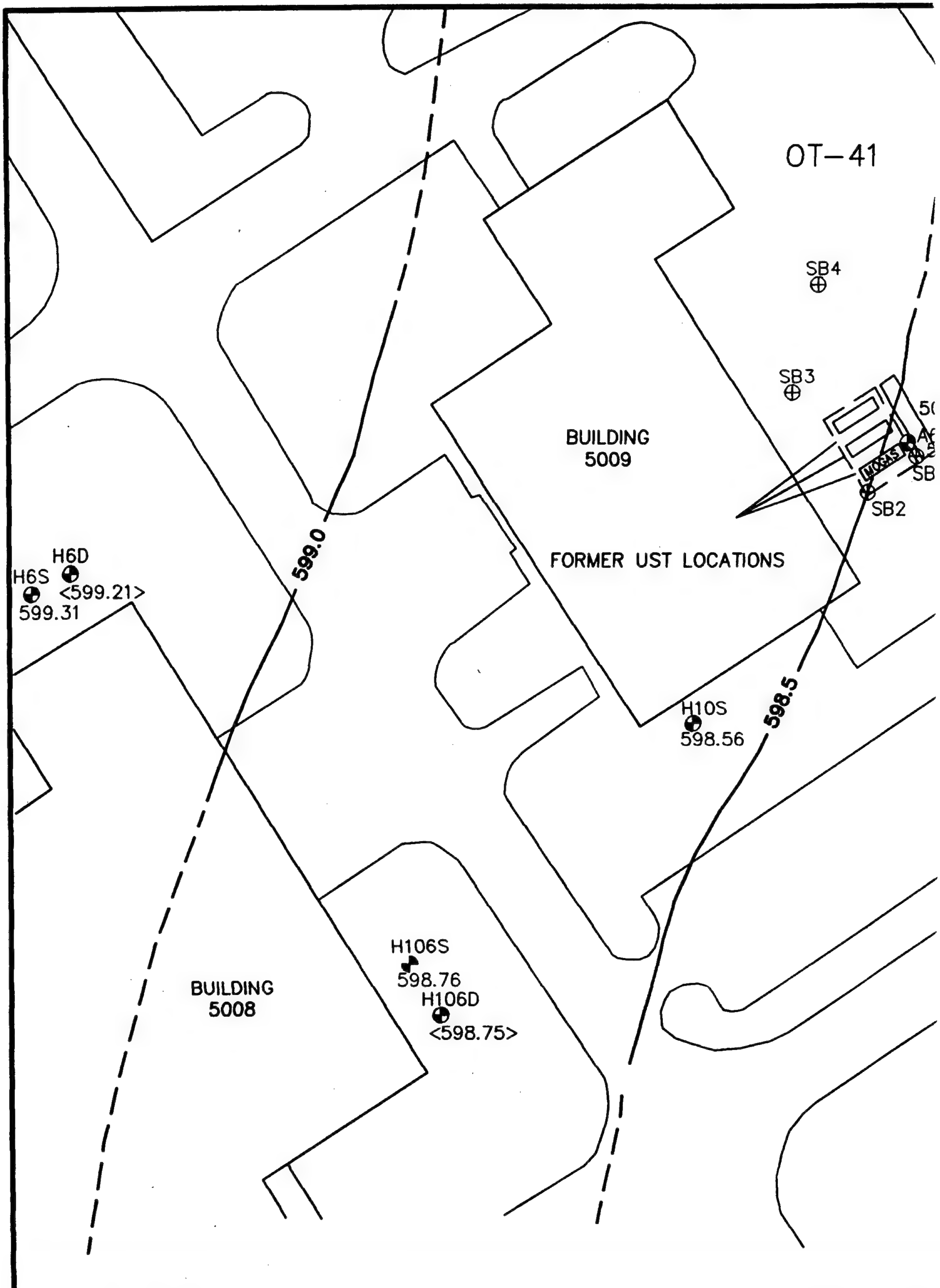

Source: ICF, 1993

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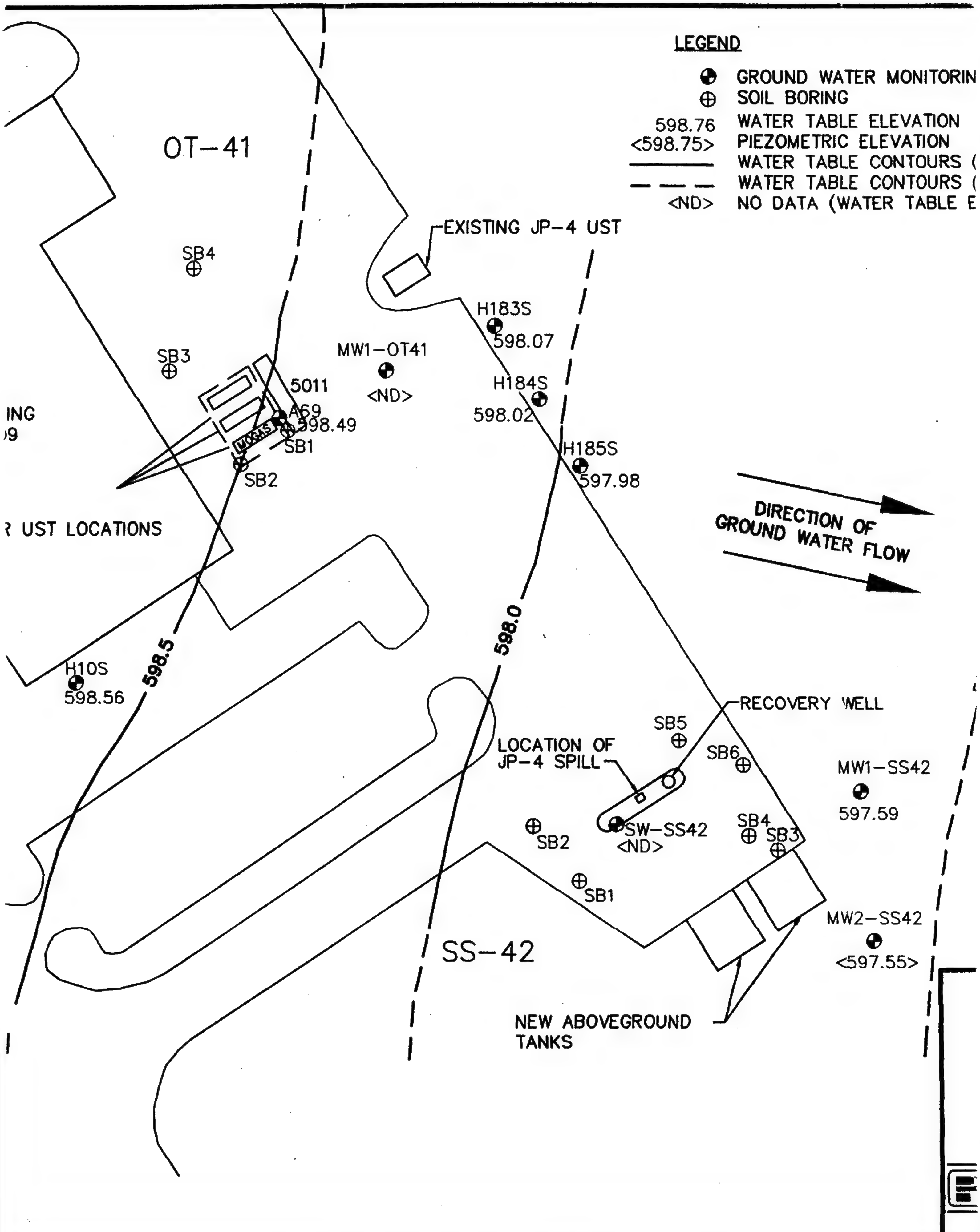
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GROUND WATER MONITORIN
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EXISTING JP-4 UST
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DIRECTION OF GROUND WATER FLOW
? UST LOCATIONS
598.5
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RECOVERY WELL
SB5
LOCATION OF JP-4 SPILL
SB6
MW1-SS42
597.59
SW-SS42
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SB4
SB3
SB1
MW2-SS42
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SS-42
NEW ABOVEGROUND TANKS

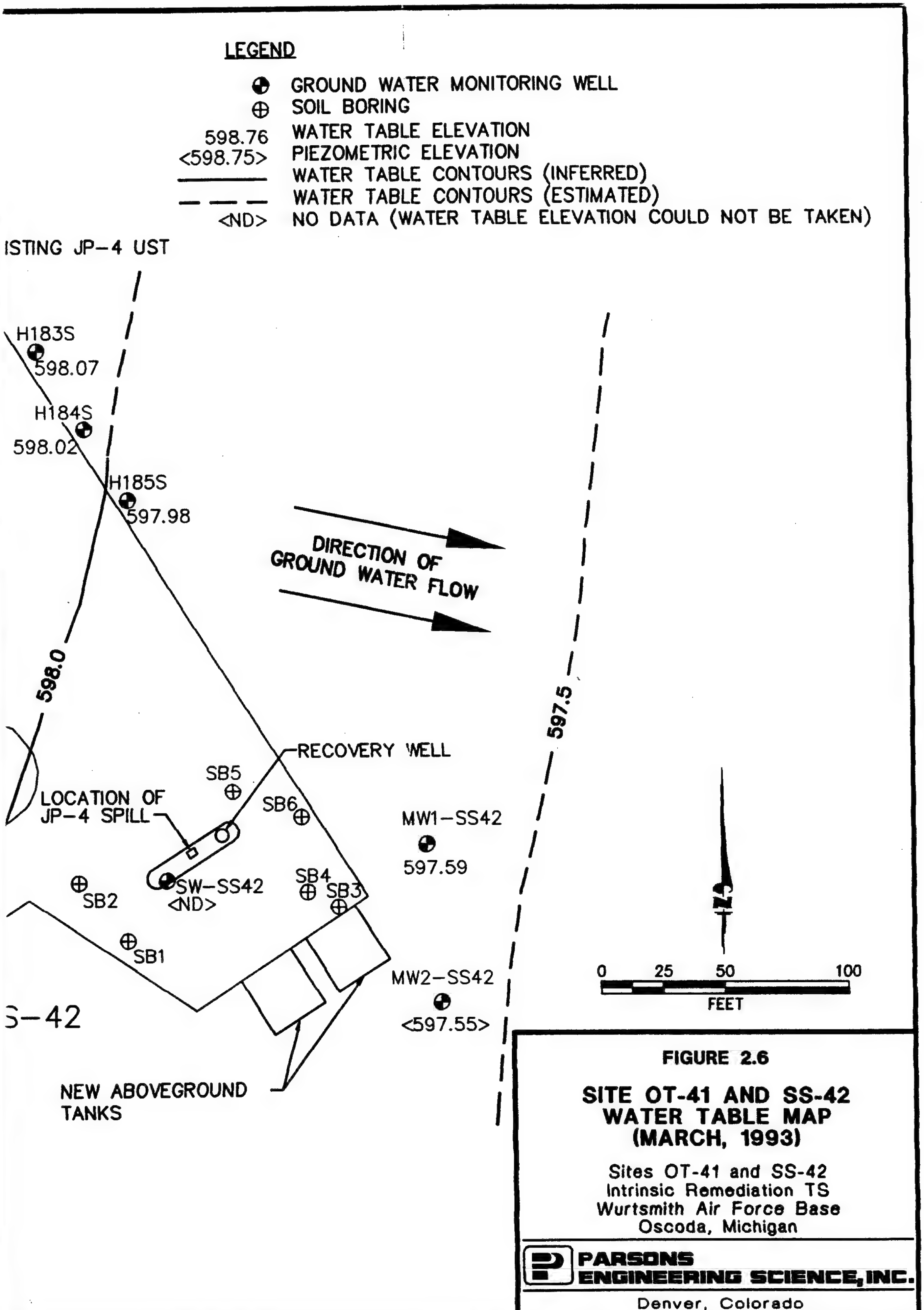


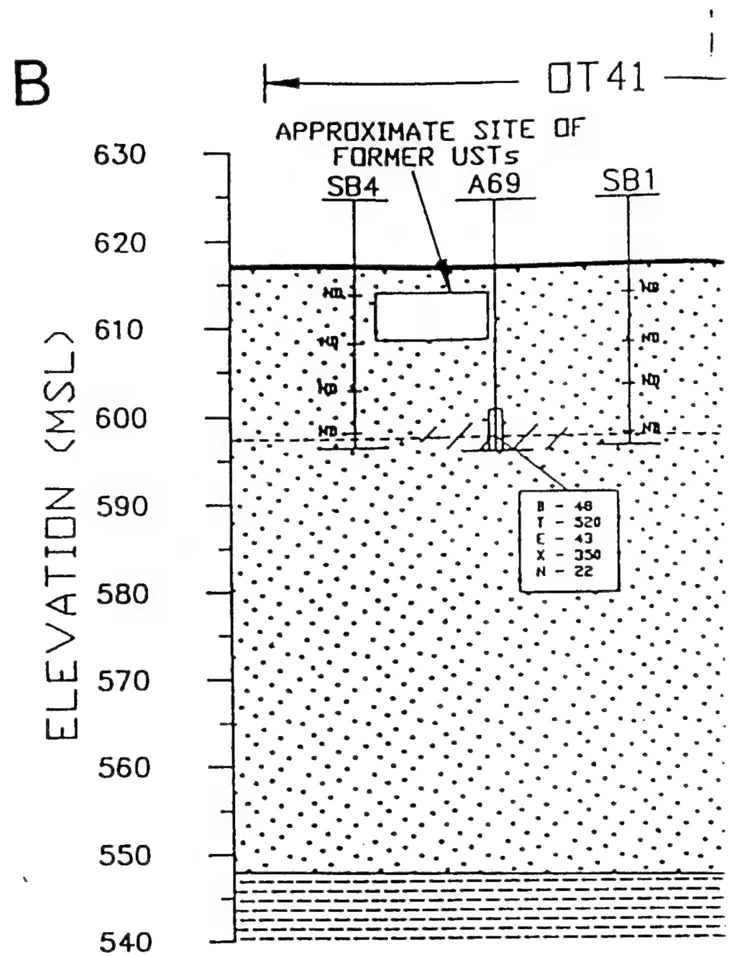
FIGURE 2.6

SITE OT-41 AND SS-42 WATER TABLE MAP (MARCH, 1993)

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado



LEGEND

SAND

SANDY GRAVEL

SILT

SILTY CLAY

CLAY

FILL

ASPHALT

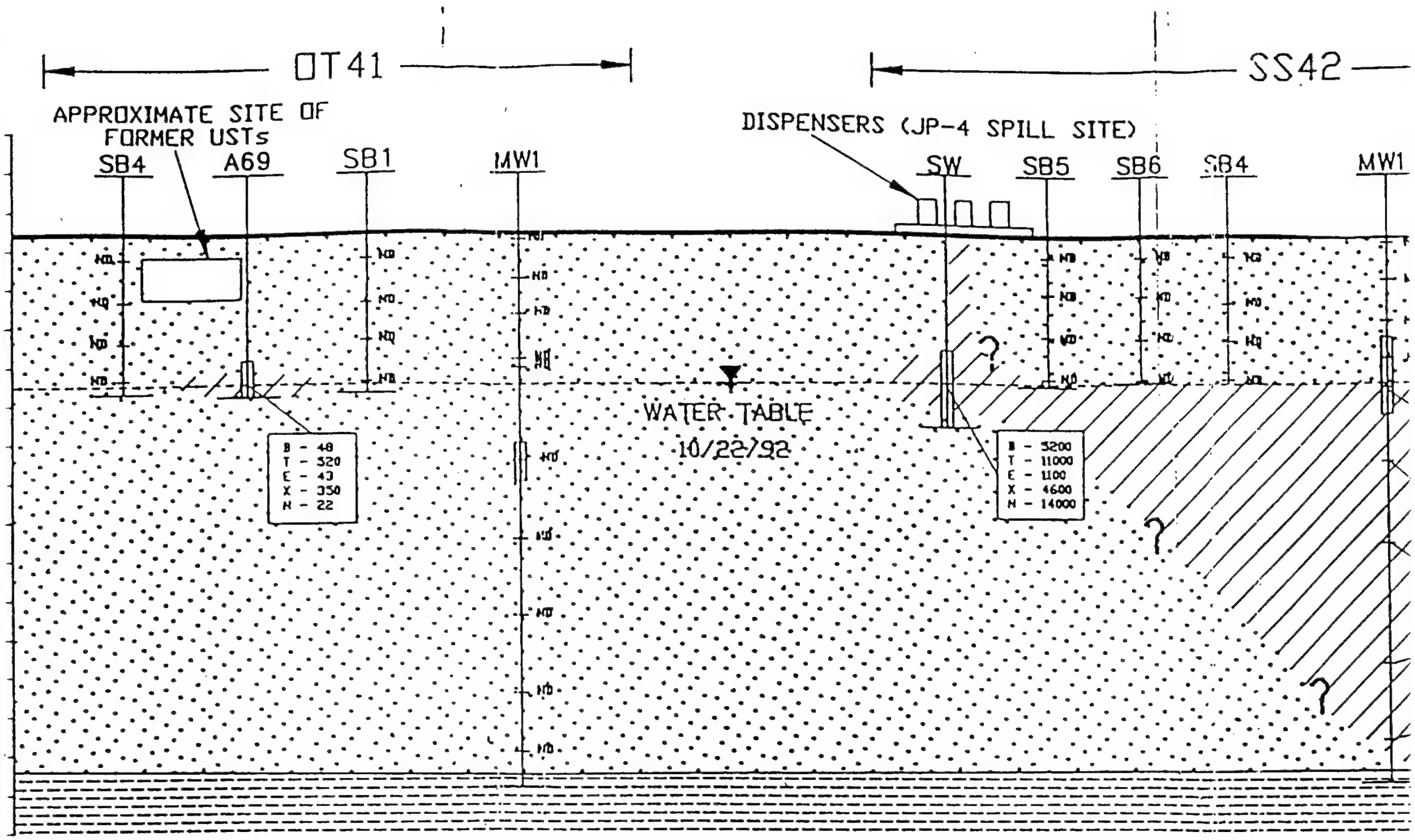
STRATIGRAPHIC CONTACT (ESTIMATED)

ESTIMATED AREA OF BTEX AND PNA DETECTIONS > MDNR TYPE A LEVELS

NOTES FOR SAMPLE RESULTS:

B - BENZENE
T - TOLUENE
E - ETHYLBENZENE
X - XYLENE
N - NAPHTHALENE

SOIL CONCENTRATIONS - ug/kg
WATER CONCENTRATIONS - ug/L
ND - NOT DETECTED AT CONCENTRATIONS > MDNR TYPE A LEVELS
ALL SAMPLES BELOW WATER TABLE ARE GROUNDWATER SAMPLES UNLESS OTHERWISE



NOT TO HOR

FOR SAMPLE RESULTS:

BENZENE
TOLUENE
ETHYLBENZENE
XYLENE
NAPHTHALENE

CONCENTRATIONS - ug/kg
R CONCENTRATIONS - ug/L
NOT DETECTED AT CONCENTRATIONS
> MDNR TYPE A LEVELS
AMPLES BELOW WATER TABLE ARE
IDWATER SAMPLES UNLESS OTHERWISE NOTED

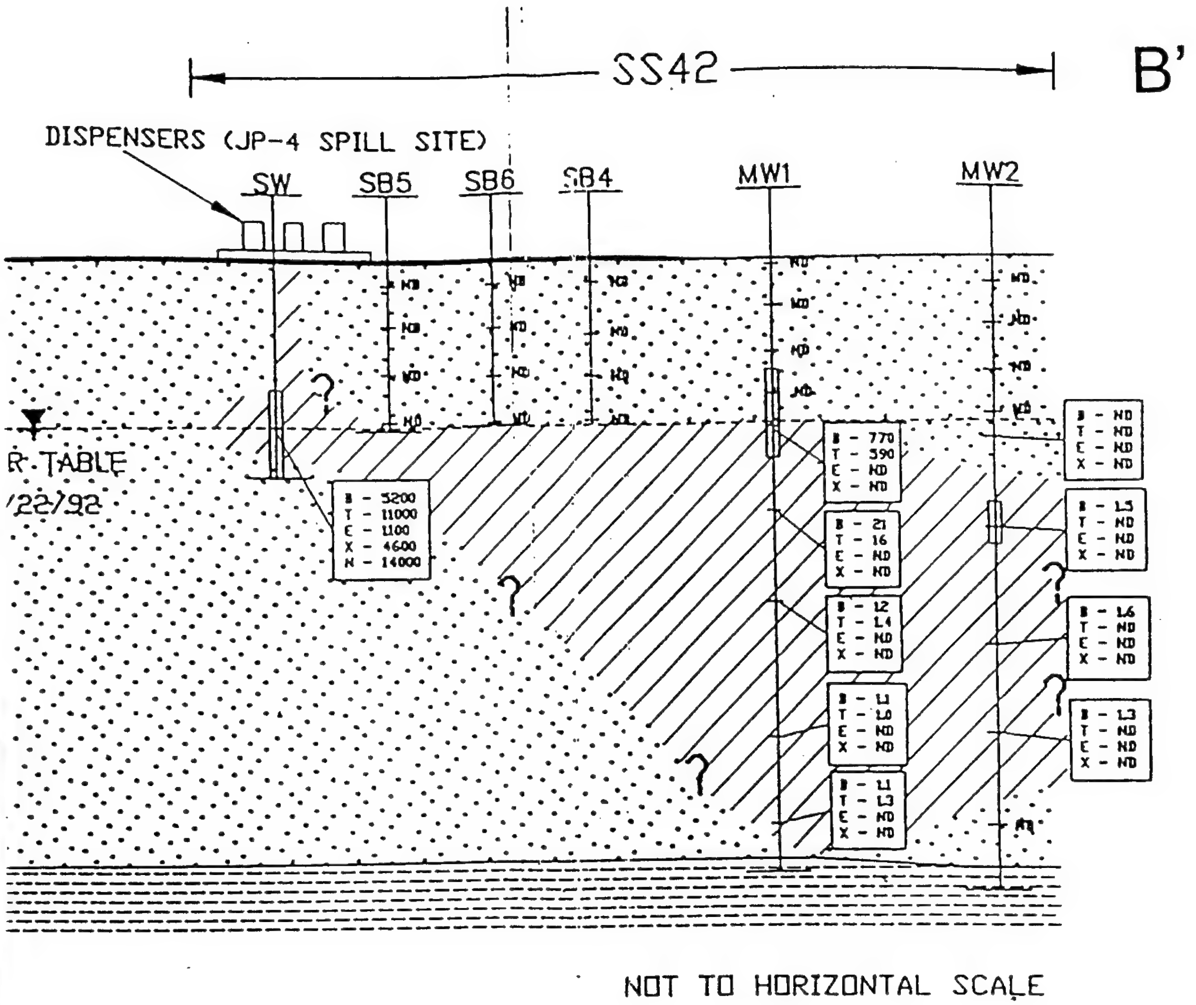


FIGURE 2.7

GENERALIZED SITE HYDROGEOLOGIC CROSS-SECTION B-B'

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

2.1.3 Soil Quality

As part of the July 1991 tank removal procedures, three composite soil samples were collected from the base of the Site OT-41 tank excavation pit at a depth of approximately 10 feet (ICF, 1994). The samples were analyzed for total petroleum hydrocarbons (TPH), polynuclear aromatic hydrocarbons (PNAs), and lead. The results of the analyses indicated TPH concentrations ranging from 1,200 milligrams per kilogram (mg/kg) to 25,600 mg/kg, and lead concentrations ranging from below method detection limits to 41 mg/kg. Two of the samples contained concentrations of several PNAs with the highest concentrations reported for naphthalene (24 mg/kg) and 2-methyl naphthalene (68 mg/kg).

As part of the RI for sites OT-41 and SS-42, a 55-station soil gas survey for benzene, toluene, ethylbenzene, and xylenes (BTEX) was conducted in 1992 by ICF Technology. (ICF, 1993). Twenty-three samples were collected at Site OT-41, with total BTEX concentrations (where detected) ranging from 53 nanoliters per liter (nl/L) to 800 nl/L. Thirty-two samples were collected at SS-42, with total BTEX concentrations ranging from 57 nl/L to 116,000 nl/L. On the basis of the soil gas survey, a contaminant plume was delineated at Site SS-42, with the highest BTEX soil gas concentrations occurring in the area immediately downgradient of the JP-4 fuel spill.

Analytical results are available for soil samples collected from the 10 soil borings and 3 monitoring wells installed in the vicinity of building 5009 during the RI in 1992 (Figure 2.5). The samples were analyzed for BTEX, MTBE, PNAs, and lead (ICF, 1993), and the results are provided in Table 2.3. None of the soil samples collected from the soil boreholes or monitoring wells contained BTEX or MTBE concentrations above method detection limits. Naphthalene was detected at a concentration of 1.5 mg/kg in the 17 to 19-foot interval from boring SB1-SS42. All other PNAs were below method detection limits. The concentrations of lead in the soils ranged from 550 micrograms per kilogram (µg/kg) to 3,300 µg/kg. Results for samples collected from the soil boreholes completed by the USGS in previous studies were not available for inclusion in this work plan.

TABLE 2.2
GROUND WATER SURFACE ELEVATIONS
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Location	Well No.	Date	Water Elevation (ft. MSL)[a/]	Depth to Water Elevation (ft. BTOC)[b/]
OT-41	MW1-OT41	11/7/92	597.86	18.26
OT-41	A69	8/15/91	601.92	14.89
		3/9/93	598.49	18.32
OT-41	H6S	3/9/93	598.07	22.74
OT-41	H10	3/9/93	598.02	21.76
OT-41	H183S	8/15/91	598.87	21.75
		3/9/93	597.98	22.64
OT-41	H184S	8/15/91	598.80	21.75
		3/9/93	598.56	21.99
OT-41	H185S	8/15/91	598.75	21.61
		3/9/93	599.31	21.05
SS-42	MW1-SS42	3/9/93	599.21	20.12
SS-42	MW2-SS42	3/9/93	598.76	19.14

[a/] ft. MSL = Feet above mean sea level
[b/] ft. BTOC = Feet below top of casing

TABLE 2.3
SOIL ANALYTICAL DATA SUMMARY
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Sample no. depth (fbgs)[a/]	Analytes Benzene mg/kg[b/]	Ethylbenzene mg/kg	Toluene mg/kg	Total Xylenes mg/kg	Napthalene mg/kg	Lead µg/kg[c/]	MTBE µg/kg
SB1-OT41							
1.8-3.8	0.01 U[d/]	0.01 U	0.01 U	0.03 U	0.18 U	1400.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	1700.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	700.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	700.00	100.00 U
SB2-OT41							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	800.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	900.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	2000.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	600.00	100.00 U
SB3-OT41							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.19 U	770.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	670.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	620.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	690.00	100.00 U
SB4-OT41							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	1000.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	810.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	800.00	100.00 U
12-14(D)[e/]	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	790.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	630.00	100.00 U

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TABLE 2.3 (Continued)
SOIL ANALYTICAL DATA SUMMARY
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Sample no. depth (fbgs)[a]	Benzene mg/kg[b]	Analytes					
		Ethylbenzene mg/kg	Toluene mg/kg	Total Xylenes mg/kg	Napthalene mg/kg	Lead µg/kg[c]	MTBE µg/kg
MW1-OT41							
0.2-2.2	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	1000.00	100.00 U
5-7	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	910.00	100.00 U
10-12	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	900.00	100.00 U
15-17	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	970.00	100.00 U
SB1-SS42							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	1300.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	780.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	820.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	1.50	620.00	100.00 U
SB2-SS42							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	2000.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	750.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	1200.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	550.00	100.00 U
SB3-SS42							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	930.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	740.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	960.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	660.00	100.00 U

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TABLE 2.3 (Continued)
SOIL ANALYTICAL DATA SUMMARY
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Sample no. depth (fbgs)[a/]	Analytes						
	Benzene mg/kg[b/]	Ethylbenzene mg/kg	Toluene mg/kg	Total Xylenes mg/kg	Napthalene mg/kg	Lead µg/kg[c/]	MTBE µg/kg
SB4-SS42							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	840.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	1600.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	820.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.20 U	660.00	100.00 U
17-19(D)	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	700.00	100.00 U
SB5-SS42							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	930.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	650.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	670.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	1200.00	100.00 U
SB6-SS42							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	850.00	100.00 U
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	670.00	100.00 U
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.17 U	720.00	100.00 U
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	990.00	100.00 U

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TABLE 2.3 (Continued)
SOIL ANALYTICAL DATA SUMMARY
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Sample no. depth (fbgs)[a/]	Analytes						
	Benzene mg/kg[b/]	Ethylbenzene mg/kg	Toluene mg/kg	Total Xylenes mg/kg	Napthalene mg/kg	Lead µg/kg[c/]	MTBE µg/kg
MW1-SS42							
0-2	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	3300.00	100.00 U
5-7	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	710.00	100.00 U
10-12	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	720.00	100.00 U
14.9-16.9	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	990.00	110.00 UJ
MW2-SS42							
2-4	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	740.00	100.00 UJ[f/]
7-9	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	1000.00	100.00 UJ
12-14	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	800.00	100.00 UJ
17-19	0.01 U	0.01 U	0.01 U	0.03 U	0.18 U	990.00	100.00 UJ

[a/] fbgs = feet below ground surface
[b/] mg/kg = milligrams per kilogram
[c/] µg/kg = micrograms per kilogram
[d/] U = undetected at associated quantitation limit
[e/] (D) = replicate of preceding sample
[f/] UJ = undetected at associated estimated quantitation limit

Source: ICF, 1993

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2.1.4 Ground Water Quality and Chemistry

Ground water analytical results are available from the three monitoring wells installed during the RI and the eight monitoring wells installed prior to RI activities (Figure 2.5). During the well drilling activities associated with the newly installed wells MW1-OT41, MW1-SS42, and MW2-SS42, grab samples of ground water were collected at 10 foot intervals from the ground water surface to the confining layer. Table 2.4 is a summary of ground water analytical data from samples obtained by the USGS (1991) in August 1991, and from the RI completed in 1993 (ICF, 1993). Ground water samples from four wells at Site OT-41 were collected by the USGS in 1991. The samples were analyzed for volatile organic compounds (VOCs), PNAs, and metals. BTEX concentrations above detection limits were reported in two of the wells. BTEX concentrations ranged from 56.6 micrograms per liter (μg/L) at H183S to 1,188 μg/L at A69. Tetrachloroethene was detected in three wells, with concentrations ranging from 3.8 μg/L at H184S to 5.3 μg/L at H185S. Naphthalene was detected in monitoring well H183S at a concentration of 2.6 μg/L and in well A69 at a concentration of 76 μg/L. Lead was detected only in well A69 at a concentration of 7.2 μg/L.

The samples collected during the RI were from both Sites OT-41 and SS-42 and were analyzed for BTEX, MTBE, PNAs, and lead. Concentrations of BTEX compounds detected during the RI are presented in cross-sectional view on Figure 2.7 and in plan view on Figure 2.8. Four wells contained BTEX concentrations above detection limits. Well A69, downgradient of the former USTs at Site OT-41, contained a total BTEX concentration of 961 μg/L. At site SS-42, wells MW1, MW2, and SW contained total BTEX concentrations ranging from 1.3 μg/L (MW2 at 53.5-56.5 feet bgs) to 219,000 μg/L (SW at 20.7 feet bgs). Approximately 19 inches of free product also was observed in monitoring well SW (southwest of the JP-4 spill) during the RI. MTBE was not reported above method detection limits in any of the ground water samples. Naphthalene was detected in monitoring well A69 (Site OT-41) at a concentration of 22 μg/L and monitoring well SW (Site SS-42) at a concentration of 14,000 μg/L. Lead was reported in three samples with concentrations ranging from 3.0 μg/L at H184S-OT41 to 10.0 μg/L at MW1-SS42.

should be 21,900

TABLE 2.4
GROUNDWATER ANALYTICAL DATA SUMMARY
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Well No.		Analytes						
Date	Depth (fbgs)[a/]	Benzene µg/L[b/]	Ethylbenzene µg/L	Toluene µg/L	Total Xylenes µg/L	Napthalene µg/L	Lead µg/L	MTBE µg/L
MW1-OT41								
10/26/92	17-22	1.0 U[c/]	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
10/26/92	29-32	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
10/26/92	39-42	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
10/27/92	49-52	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
10/27/92	59-62	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
10/27/92	68-71	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
A69-OT41								
8/15/91	NA	780.0	240.0	48.0	44.0	76.0	7.2	
10/23/92	18.75	48.0	43.0	520.0	350.0	22.0	NA	50.0 U
H183S-OT41								
8/15/91	NA[d/]	1.7	3.9	14.0	37.0	2.6	ND	
10/22/92	22.7	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
H184S-OT41								
8/15/91	NA	ND[e/]	ND	ND	ND	ND	ND	
10/22/92	22.9	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0	50.0 U

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TABLE 2.4 (Continued)
GROUNDWATER ANALYTICAL DATA SUMMARY
SITES OT-41 and SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Well No.		Analytes						
Date	Depth (fbgs)[a/]	Benzene μg/L[b/]	Ethylbenzene μg/L	Toluene μg/L	Total Xylenes μg/L	Napthalene μg/L	Lead μg/L	MTBE μg/L
H185S-OT41								
8/15/91	NA	ND	ND	ND	ND	ND	ND	
10/22/92	22.8	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.6	50.0 U
H6S-OT41								
10/27/92	21.8	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
H10S-OT41								
10/22/92	NA	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
H62-OT41								
10/27/92	NA	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
MW1-SS42								
11/3/92	10-22	770.0 J[f/]	50.0 UJ	590.0 J	150.0 UJ	5.0 U	3.0 U	2500.0 UJ[g/]
11/3/92	28.9-31.9	21.0	1.0 J	16.0	3.0 U	5.0 U	10.0	50.0 U
11/3/92	39-42	12.0	1.0 U	1.4	3.0 U	5.0 U	3.0 U	50.0 U
11/3/92	55-58	1.1	1.0 U	1.0	3.0 U	5.0 U	3.0 U	50.0 U
11/4/92	64-67	1.1	1.0 U	1.3 J	3.0 U	5.0 U	3.0 U	50.0 UJ
11/4/92	64-67(D)[h/]	1.1	1.0 U	1.2 J	3.0 U	5.0 U	3.0 U	50.0 UJ

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TABLE 2.4 (Continued)
GROUNDWATER ANALYTICAL DATA SUMMARY
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Well No.		Analytes						
Date	Depth (fbgs)[a/]	Benzene μg/L[b/]	Ethylbenzene μg/L	Toluene μg/L	Total Xylenes μg/L	Napthalene μg/L	Lead μg/L	MTBE μg/L
MW2-SS42								
11/5/92	18.4-21.2	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
11/5/92	29-32	1.5	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
11/5/92	43-46	1.6	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
11/5/92	53.5-56.5	1.3	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
11/5/92	64-67	1.0 U	1.0 U	1.0 U	3.0 U	5.0 U	3.0 U	50.0 U
SW-SS42								
10/24/92	20.7	5200.0	1100.0	11000.0	4600.0	14000.0	3.0 U	2500.0 U

[a/] fbgs = feet below ground surface
[b/] μg/L = micrograms per Liter
[c/] U = undetected at associated detected limits
[d/] ND = not detected
[e/] NA = not available
[f/] J = estimated
[g/] UJ = undetected at associated estimated detection limit
[h/] (D) = duplicate of previous sample

Source: ICF, 1994

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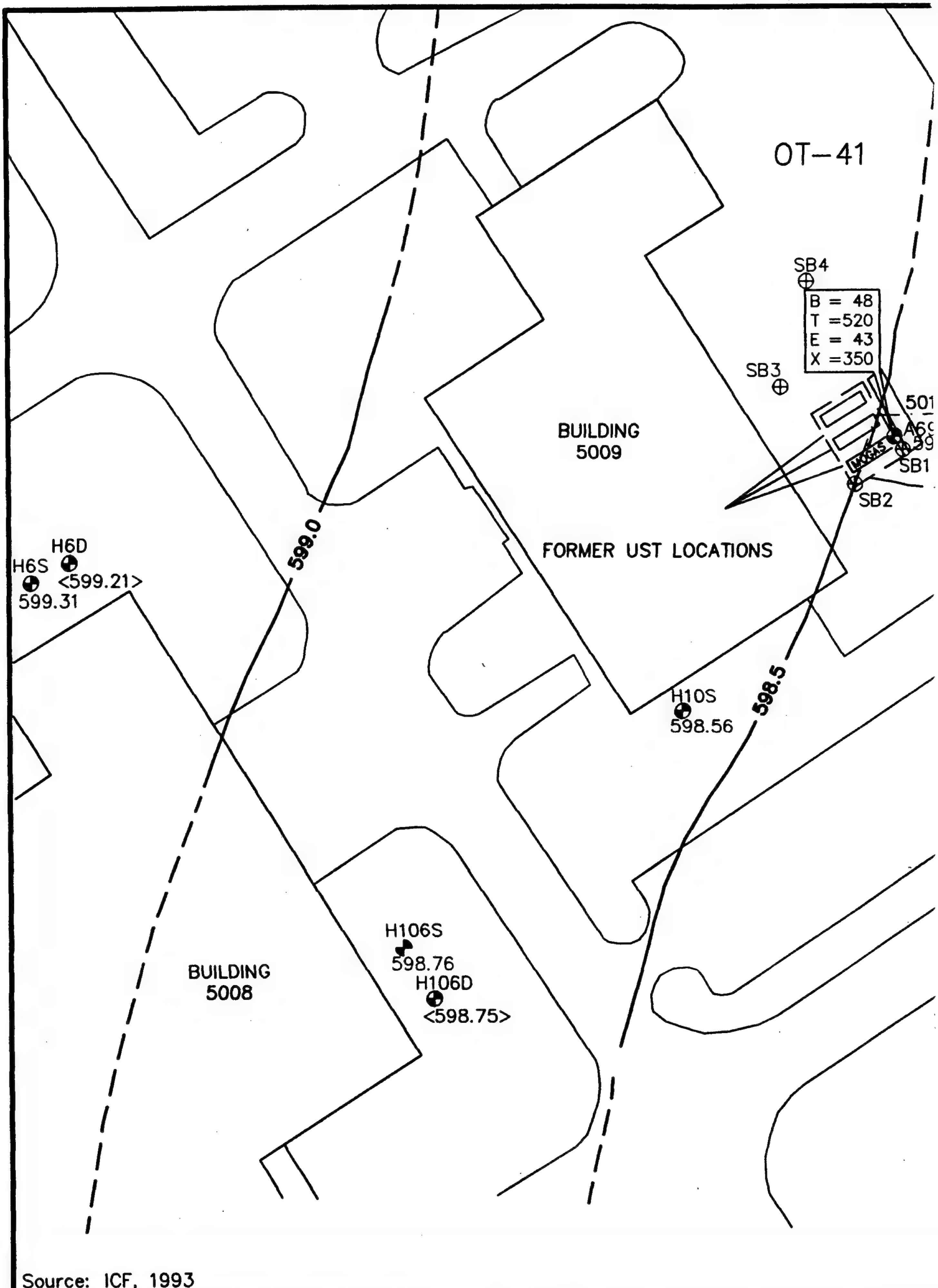

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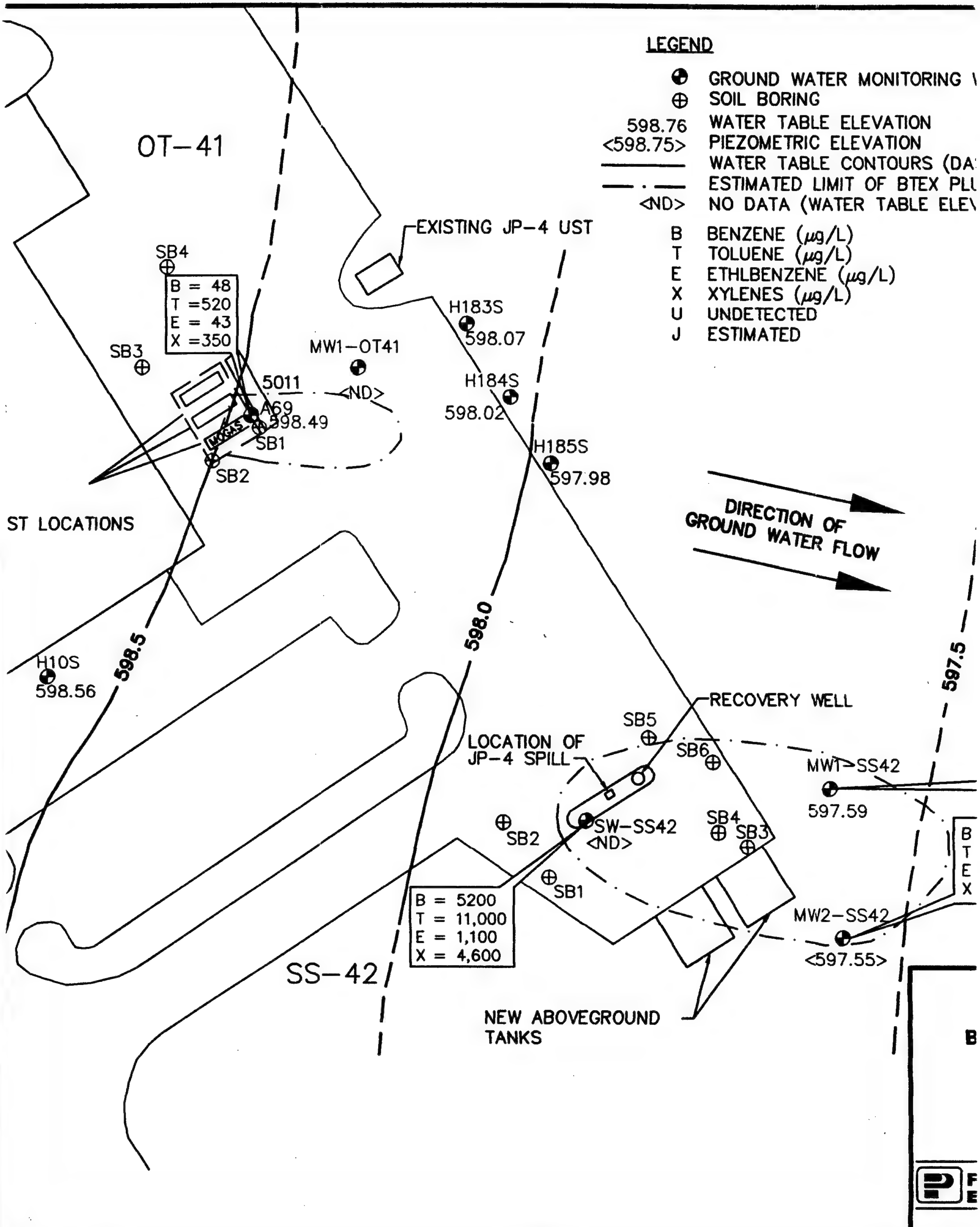
LEGEND
GROUND WATER MONITORING \
SOIL BORING
598.76 WATER TABLE ELEVATION
<598.75> PIEZOMETRIC ELEVATION
WATER TABLE CONTOURS (DA
ESTIMATED LIMIT OF BTEX PLU
<ND> NO DATA (WATER TABLE ELE\
B BENZENE (μg/L)
T TOLUENE (μg/L)
E ETHLBENZENE (μg/L)
X XYLENES (μg/L)
U UNDETECTED
J ESTIMATED
OT-41
EXISTING JP-4 UST
SB4
B = 48
T =520
E = 43
X =350
SB3
MW1-OT41
<ND>
5011
A69
598.49
MOGAS
SB1
SB2
H183S
598.07
H184S
598.02
H185S
597.98
ST LOCATIONS
DIRECTION OF GROUND WATER FLOW
598.5
598.0
597.5
H10S
598.56
RECOVERY WELL
SB5
SB6
LOCATION OF JP-4 SPILL
MW1-SS42
597.59
SB2
SW-SS42
<ND>
SB4
SB3
SB1
B = 5200
T = 11,000
E = 1,100
X = 4,600
MW2-SS42
<597.55>
SS-42
NEW ABOVEGROUND TANKS
B
T
E
X
B

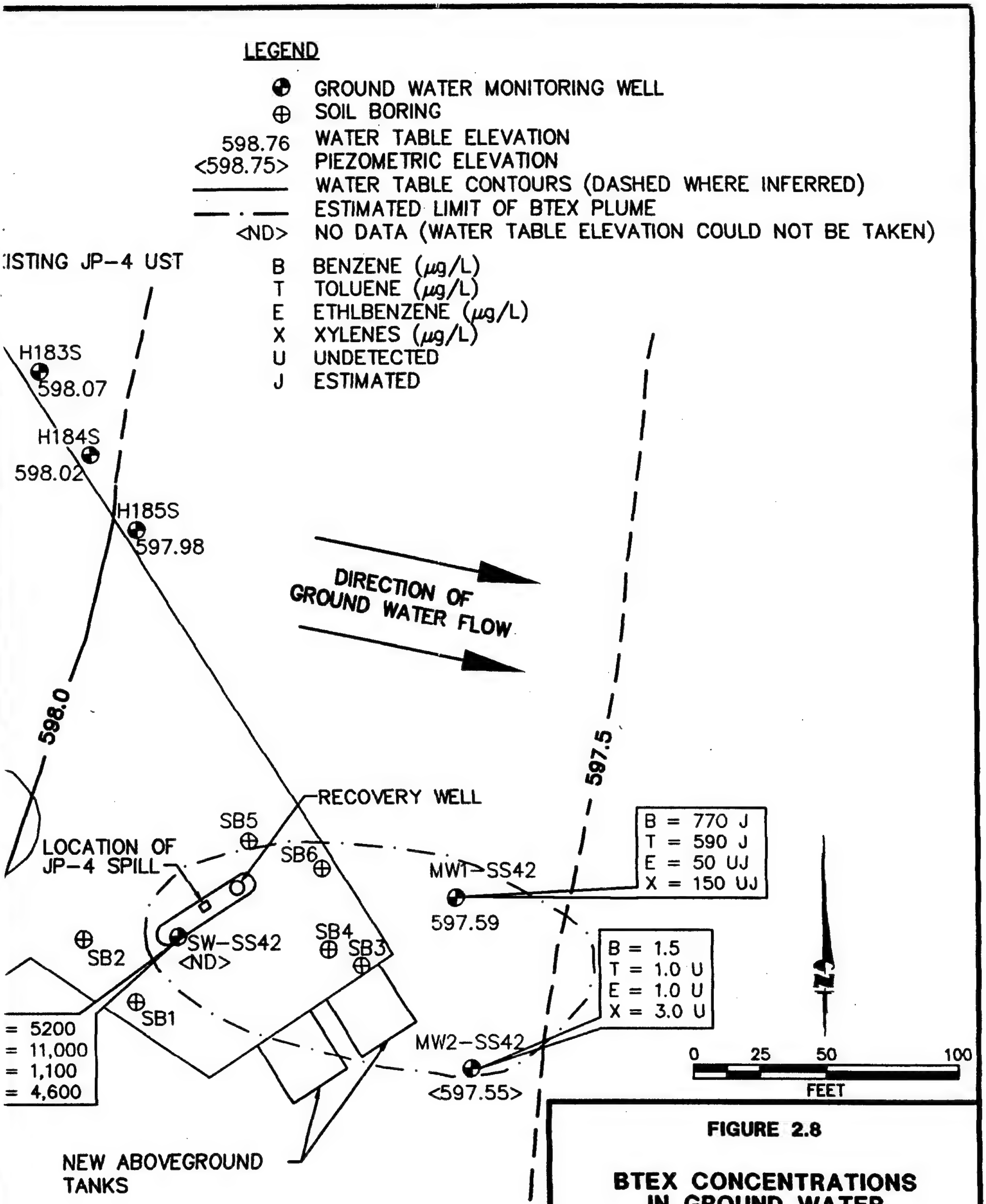

FIGURE 2.8

BTEX CONCENTRATIONS IN GROUND WATER

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

2.2 DEVELOPMENT OF CONCEPTUAL MODEL

A conceptual model is a three-dimensional representation of a hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. The purpose of the conceptual model is to integrate available data so that a coherent representation of the ground water flow and contaminant transport system can be developed. The conceptual model for Sites OT-41 and SS-42 will be used to aid in selecting additional data collection points and to help develop the Bioplume II model.

Successful conceptual model development involves:

- Defining the problem to be solved;
- Selecting the model;
- Designing the conceptual model;
- Integrating available data, including
    - Local geologic and topographic data,
    - Hydraulic data,
    - Site stratigraphic data,
    - Contaminant concentration and distribution data; and
- Determining additional data requirements.

2.2.1 Initial Conceptual Model

Site hydrogeologic data were previously integrated to produce the hydrogeologic cross section of the Base (ICF, 1993). Cross section B-B' (Figure 2.7) shows the dominant hydrostratigraphic units present at the sites and the water table elevation. Figure 2.6 is a ground water surface map prepared using March 1993 ground water elevation data (ICF, 1993).

In the vicinity of the site, ground water exists under unconfined conditions in glacial outwash sands. Based on available data, Parsons ES will model the site as an unconfined, medium- to coarse-grained sand aquifer. Ground water flows east-southeast at the site.

This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

Free product has been reported at well SW-SS42 (ICF, 1993). If free product is present, it may be necessary to use the fuel/water partitioning model of Bruce *et al.* (1991) or Cline *et al.* (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-product phase into the ground water. In order to use this model, samples of free product, if present, will be collected and analyzed for mass fraction of BTEX compounds.

2.2.2 Potential Pathways and Receptors

Potential preferential contaminant migration pathways, such as ground water discharge points and subsurface utility corridors (artificial conduits), will be identified during the field work phase of this project. The primary potential migration paths for contaminants at Sites OT-41 and SS-42 are from soil to the ground water and from the ground water to potential receptors via consumption or other use. Shallow ground water beneath the sites flows towards Van Etten Lake and Van Etten Creek, approximately 1 mile east of the sites. It is unlikely that detectable concentrations of contaminants will reach the Van Etten River because of the processes of dilution, dispersion, and biodegradation. Exposure to contaminated ground water from the surficial aquifer may be a completed pathway because the surficial aquifer may locally be used as a drinking water source. Primary potable water supplies for the Base are obtained from on-base wells drilled into the shallow unconfined aquifer. The nearest downgradient supply well is approximately 2500 feet east of the sites.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the TS and to demonstrate that intrinsic remediation of fuel-related contaminants is occurring at Sites OT-41 and SS-42, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the TS.

Physical hydrogeologic characteristics to be determined for Sites OT-41 and SS-42 include:

- Depth from measurement datum to the ground water surface in existing monitoring wells;
- Locations of potential ground water recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimate of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Temperature; and
- Determination of extent and thickness of free- and residual-phase product.

Chemical hydrogeologic characteristics to be determined for Sites OT-41 and SS-42 include:

- Dissolved oxygen (DO) concentration;
- Specific conductance;
- pH;

- Chemical analysis of free product (if present) to determine mass fraction of BTEX; and
- Additional chemical analysis of ground water and soil for the parameters listed in Table 3.1.

In order to obtain these data, cone penetrometer testing (CPT) in conjunction with laser-induced fluorometry (LIF) and sampling of ground water, free product (if present), and soil will be completed at Sites OT-41 and SS-42 in support of the TS. New ground water monitoring points will be installed, as needed, to support the intrinsic remediation option and to provide permanent downgradient ground water monitoring points. The following sections describe the procedures that will be followed when collecting additional site-specific data. The CPT/LIF system is described in Section 3.1. Procedures for soil sample collection to verify CPT/LIF data are described in Section 3.1.2. Procedures for the installation of new monitoring points are described in Section 3.2. Procedures for the sampling of existing ground water monitoring wells and newly installed ground water monitoring points are described in Section 3.3. Procedures for the measurement of aquifer parameters (e.g., hydraulic conductivity) are described in Section 3.4.

3.1 CONE PENETROMETRY

Subsurface conditions at Sites OT-41 and SS-42 will be characterized using CPT coupled with LIF. Cone penetrometry is an expeditious and effective means of analyzing the stratigraphy of a site by measuring the resistance of different soil types against the conical probe of the penetrometer as it is pushed into the subsurface. The resistance on the pressure tip and friction sleeves on the side of the cone are then correlated to soil cores collected to calibrate the CPT readings to the lithologies present at the site. Methodologies for the collection of soil core data are described in Section 3.1.2. Depending on the type of soil, site conditions, and experience of the crew operating the equipment, CPT can provide large amounts of data for a fraction of the cost of actual soil borings.

TABLE 3.1
ANALYTICAL PROTOCOL FOR
GROUND WATER AND SOIL
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

MATRIX	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Total Iron	Colorimetric, HACH Method 8008	F
Ferrous Iron (Fe^{2+})	Colorimetric, HACH Method 8146	F
Ferric Iron (Fe^{3+})	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034	F
Sulfate	Colorimetric, HACH Method 8051	F
Nitrate	Titrimetric, HACH Method 8039	F
Nitrite	Titrimetric, HACH Method 8507	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	HACH 16046 DO Meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1	F
Carbon Dioxide	Titrimetric, HACH Method 1436-01	F
Alkalinity (Carbonate [CO_3^{2-}] and Bicarbonate [HCO_3^-])	F = Titrimetric, HACH Method 8221 L = EPA method 310.1	F L
Nitrate + Nitrite	EPA Method 353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane	RSKSOP-147	L
Dissolved Organic Carbon	RSKSOP-102	L
VOCs	RSKSOP-148	L
Fuel Carbon	RSKSOP-148	L
SOIL		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	RSKSOP-124, modified	L
Total Hydrocarbons	RSKSOP-174	L
FREE PRODUCT		
BTEX Mass Fraction	GC/MS, Direct Injection	L

CPT will be conducted using the US Army Corps of Engineers' (USACE's) cone penetrometer truck. This equipment consists of an instrumented probe that is forced into the ground using a hydraulic load frame mounted on a heavy truck, with the weight of the truck providing the necessary reaction mass. The penetrometer equipment is housed in a stainless steel, dual-compartment body mounted on a 43,000-pound, triple-axle Kenworth truck chassis powered by a turbo-charged diesel engine. The weight of the truck and equipment is used as ballast to achieve the overall push capability of 39,000 pounds. This push capacity may be limited in tight soils by the structural bending capacity of the 1.80-inch outside-diameter (OD) push rods, rather than by the weight of the truck. The current 39,000-pound limitation is intended to minimize the possibility of push-rod buckling. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame.

The penetrometer probe is of standard dimensions, having a 1.80-inch OD, 60-degree conical point with sacrificial tip, and a 8.0-inch-long by 1.80-inch-OD friction sleeve. Inside the probe, two load cells independently measure the vertical resistance against the conical tip and the side friction along the sleeve. Each load cell is a cylinder of uniform cross-section which is instrumented with four strain gauges in a full-bridge circuit. Forces are sensed by the load cells, and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data are digitized, recorded, and plotted by computer in the penetrometry truck. A grout tube also runs down the push cylinder to allow the introduction of bentonite or cement-bentonite grout to the hole in order to seal the CPT hole. The USACE CPT is not equipped to monitor pore pressure; therefore, the location of the water table will not be measured using the CPT apparatus. However, evaluation of point and sleeve stresses can often provide an estimated depth to ground water. The penetrometer is usually advanced vertically into the soil at a constant rate of 2 centimeters per second, although this rate must sometimes be reduced, such as when hard layers are encountered. Penetration, dissipation, and resistivity data will be used to determine site layering as it is encountered in the field.

The known propensity of aromatic or chlorinated hydrocarbons to fluoresce under ultraviolet wavelengths has allowed the use of LIF technology, in conjunction with CPT technology, to detect soil characteristics and hydrocarbon contamination simultaneously. The LIF system has a 0.25-inch sapphire window in the side of the cone that allows a laser to scan for fluorescent compounds as the LIF penetrometer rod pushes through the

soil. Assuming that aromatic hydrocarbons are simultaneously solvenated with other fuel-hydrocarbon constituents, the magnitude of aromatic fluorescence is indicative of hydrocarbon contamination in a soil matrix. Fiber optic cables connected to the laser spectrometer, and a 6-pair electrical conductor connected to the CPT data acquisition system, are routed through the interior of the push tubes to the CPT probe.

The basic components of a LIF instrument are a nitrogen laser, a fiber optic probe, a monochromator for wavelength resolution of the return fluorescence, a photomultiplier tube to convert photons into an electrical signal, a digital oscilloscope for waveform capture, and a control computer. The fiber optic probe for the cone penetrometer consists of a delivery and collection fibers, a protective sheath, a fiber optic mount within the cone, and a 0.25-inch sapphire window (Figure 3.1).

The results of each CPT/LIF push will be available 2 or 3 minutes after the completion of each hole. Graphs showing cone resistance, sleeve friction, soil classification, fluorescence intensity, and wavelength will be plotted by USACE at the conclusion of each penetration and presented to the Parsons ES field scientist in order to allow investigative decisions to be based on the most current information.

3.1.1 CPT/LIF Testing Strategy

The purpose of the CPT/LIF testing at Sites OT-41 and SS-42 is to determine subsurface stratigraphy, and to better define the areal and vertical extent of residual fuel hydrocarbons in the unsaturated zone and the dissolved-phase plume(s) in the ground water. The cone penetrometer will be pushed from ground surface to below contamination, or up to 45 feet, depending on contaminant distribution. It is anticipated that 16 multi-level CPT/LIF points will be necessary to define the edges of the contaminant plume(s). Figure 3.2 shows the location of the proposed CPT/LIF points at Sites OT-41 and SS-42.

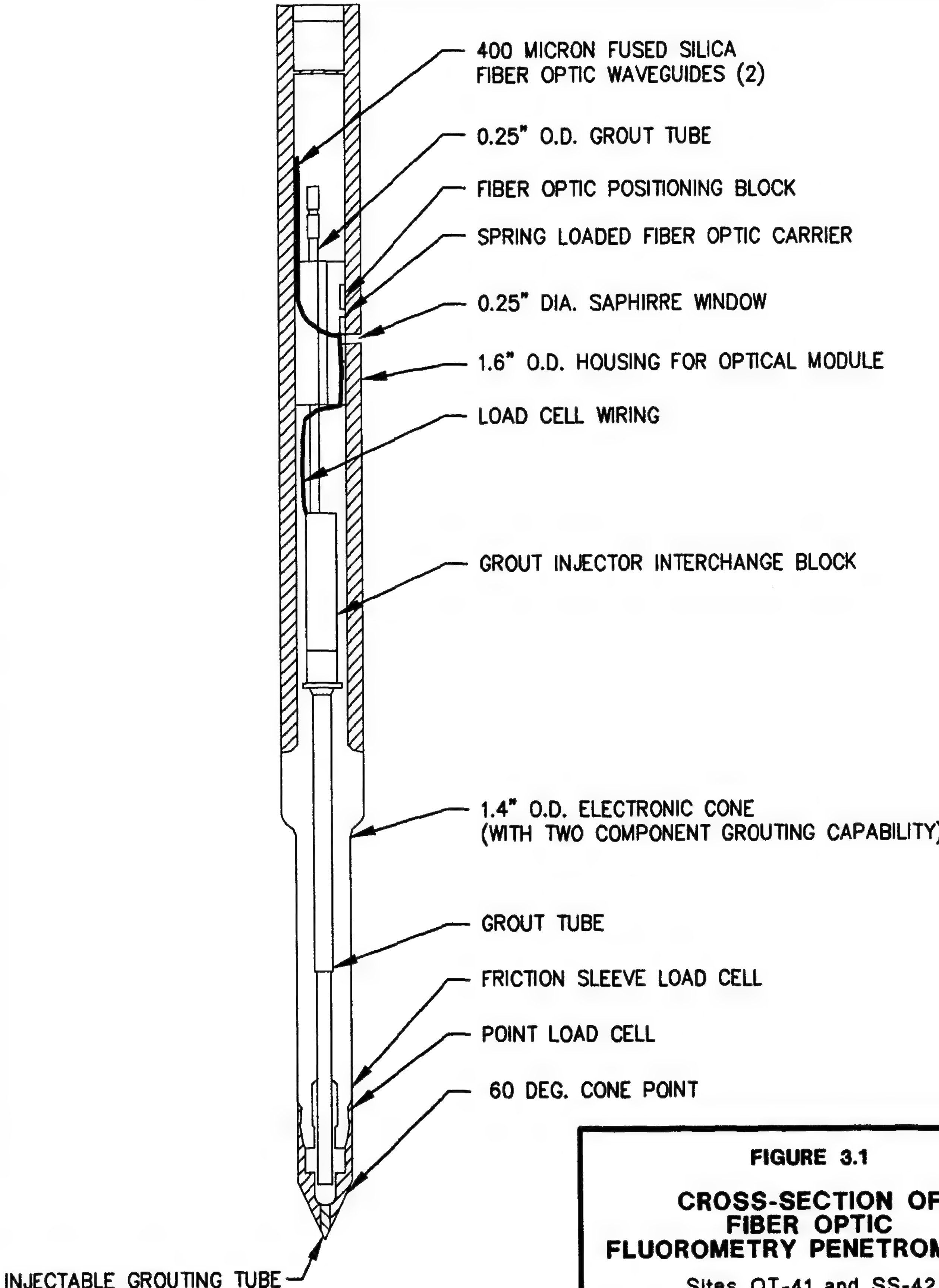

FIGURE 3.1

CROSS-SECTION OF FIBER OPTIC FLUOROMETRY PENETROMETER

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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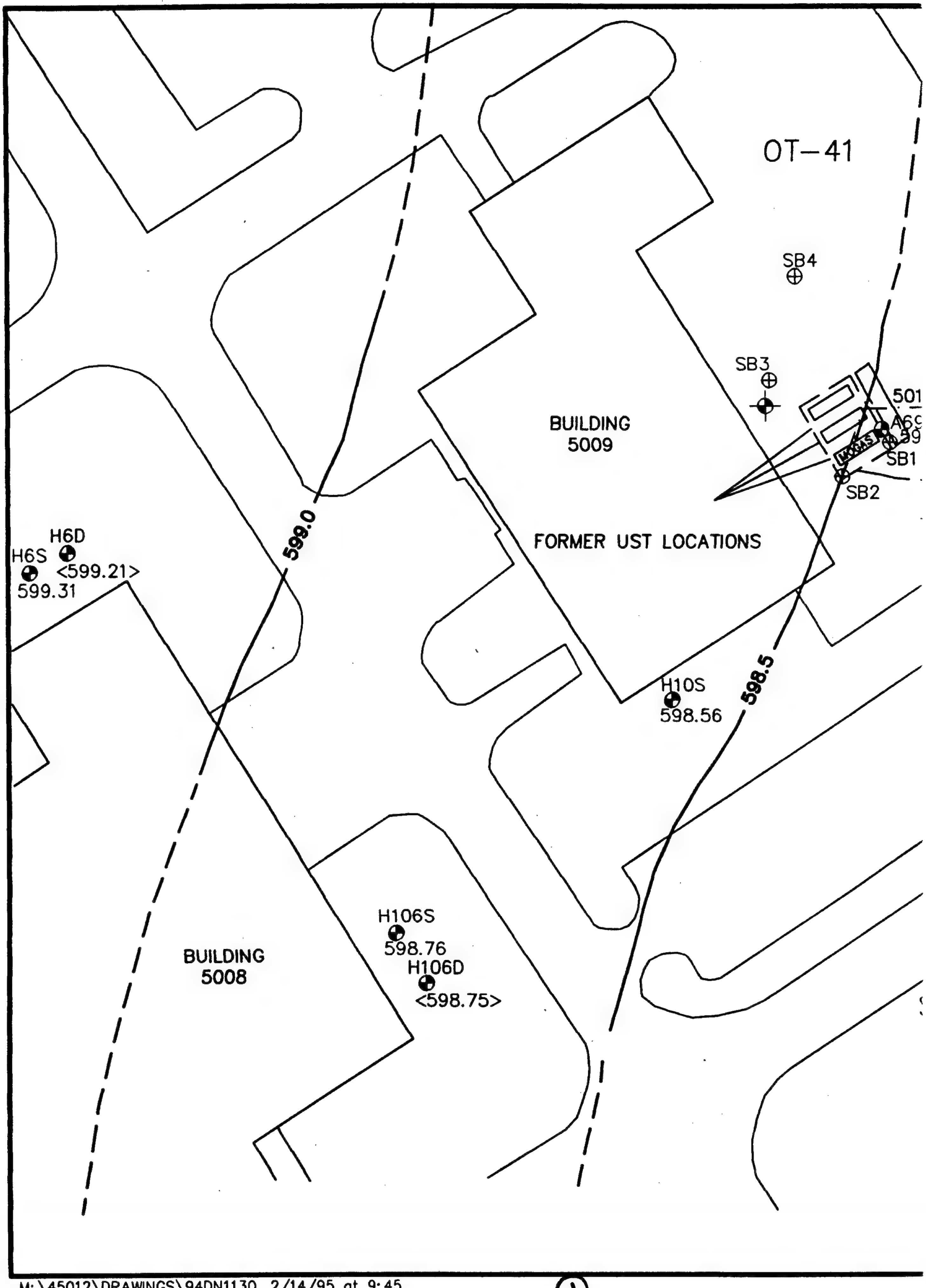
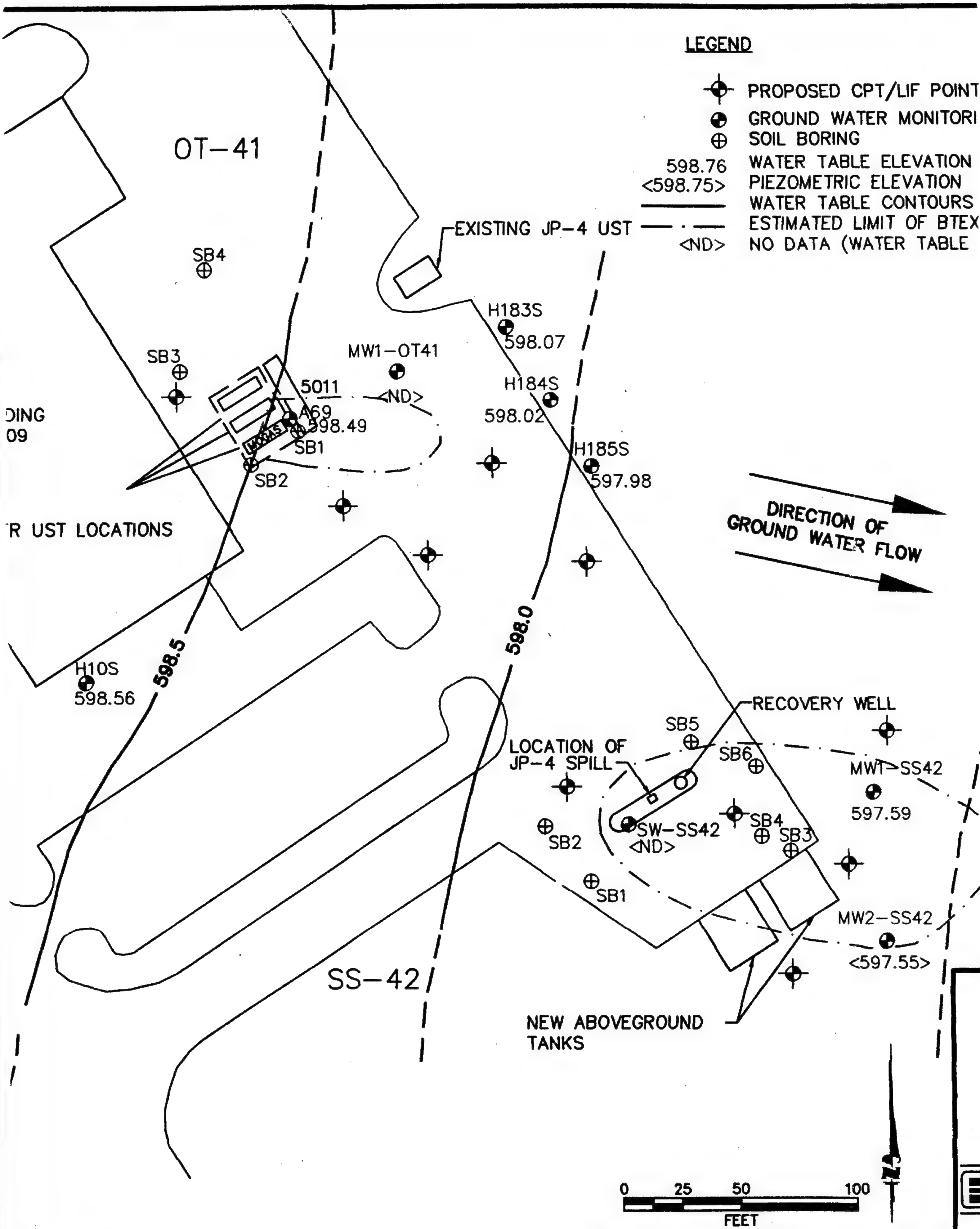

OT-41
SB4
SB3
501
MOGAS
SB1
SB2
BUILDING
5009
FORMER UST LOCATIONS
599.0
H6D
H6S
<599.21>
599.31
598.5
H10S
598.56
H106S
598.76
H106D
<598.75>
BUILDING
5008


LEGEND
PROPOSED CPT/LIF POINT
GROUND WATER MONITORI
SOIL BORING
598.76 WATER TABLE ELEVATION
<598.75> PIEZOMETRIC ELEVATION
WATER TABLE CONTOURS
ESTIMATED LIMIT OF BTEX
<ND> NO DATA (WATER TABLE
OT-41
EXISTING JP-4 UST
SB4
SB3
MW1-OT41
<ND>
5011
A69
598.49
SB1
SB2
H183S
598.07
H184S
598.02
H185S
597.98
DING
09
R UST LOCATIONS
MOGAS
DIRECTION OF GROUND WATER FLOW
598.5
598.0
H10S
598.56
RECOVERY WELL
LOCATION OF JP-4 SPILL
SB5
SB6
MW1-SS42
597.59
SW-SS42
<ND>
SB4
SB3
SB2
SB1
MW2-SS42
<597.55>
SS-42
NEW ABOVEGROUND TANKS
0 25 50 100
FEET

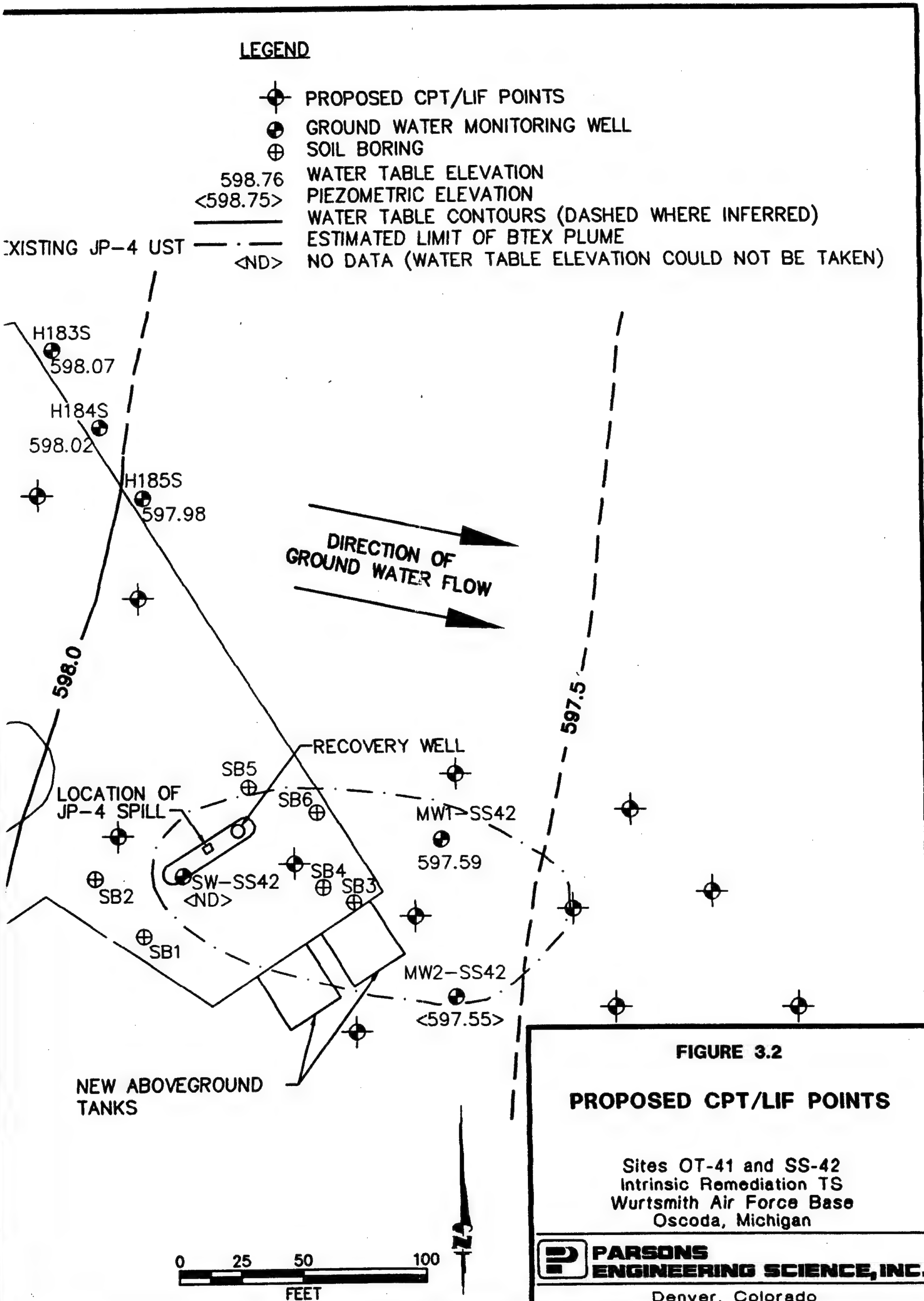


FIGURE 3.2

PROPOSED CPT/LIF POINTS

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

3

Sampling will begin within the area of known contamination. Moving downgradient (east-southeast), samples will be collected using the CPT/LIF and ground water sampling until clean soil and ground water are encountered. Through an iterative process, moving forward and backward, the leading edge of the plume will be defined. Sampling will then proceed laterally (i.e., to the north and south) until the lateral extent of the leading edge of the plume is fully defined. Evidence of a plume at Site OT-41 was not documented in the downgradient wells in previous sampling efforts. The extent of the plume at Site OT-41 is thought to be limited. In addition to defining the downgradient extent of the plume, it may be necessary to define conditions at one additional location upgradient of the plume.

At both sites, one upgradient point will be located to help determine background conditions. At Site OT-41, an additional five multilevel monitoring points will be established to define the extent of contamination. At Site SS-42, an additional nine multilevel monitoring points will be established to define the extent of the dissolved BTEX plume. Figure 3.2 shows the proposed locations of data collection points.

All necessary digging permits will be obtained by Base personnel prior to mobilizing to the field. Base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed CPT/LIF locations indicated in Figure 3.2. AFCEE will be responsible for supplying a certified driller for the duration of the field work (if applicable). Base personnel will be responsible for identifying the location of all utility lines, USTs) fuel lines, or any other underground infrastructure prior to any CPT activities.

3.1.2 Soil Core Sampling and Analysis

To calibrate CPT/LIF data, soil cores will be collected at selected test locations at Sites OT-41 and SS-42. Soil coring will involve coring the suspected area of contamination from approximately 4 feet above the contamination to approximately 4 feet below the contamination to verify/validate the CPT/LIF data. These soil cores will be located near the CPT sampling locations to allow data comparison and verification. USACE will provide the equipment and personnel necessary to complete this activity during the period from June 19 through July 2, 1995. One-foot resolution of soil cores for verification purposes will be considered sufficient for the intrinsic remediation demonstration at Sites OT-41 and SS-42.

A Hoggen Toggler® sampler generally can be used to collect "complete" soil samples at any desired depth within the range of the driving apparatus. The sampler is coupled to the penetrometer rod and pushed into the soil with the same equipment used for CPT/LIF. While the Hoggen Toggler® cone is in position, soil is prevented from entering the sampling tube until the desired depth is achieved. When the sampler has been pushed to the depth at which the soil sample is to be taken, the sampling unit is raised a few inches and the Hoggen Toggler® apparatus is opened. After opening the Hoggen Toggler® attachment, a soil section is cut and the sampling apparatus is then pulled from the ground as quickly as possible. The Hoggen Toggler® sampling apparatus allows collection of 8-inch-long by 1-inch inside-diameter (ID) continuous samples. Recovery efficiencies for samples in saturated soils are often reduced, or the samples are compromised, because of spillage of the soil from the device after extraction. To mitigate this problem, soil samples will be compressed *in situ* with the penetrometer and Hoggen Toggler® assembly to expel the pore water before extraction. Compressed soil samples can then be extracted and measured to give a description of the soil stratigraphy accurate for the length of soil core taken.

If the Hoggen Toggler® sampling techniques described above are not appropriate for the characterization of Sites OT-41 and SS-42, continuous soil samples will be obtained from conventional soil boreholes using a split-barrel, continuous sampling device or another similar method judged acceptable by the Parsons ES field scientist. Procedures will be modified, if necessary, to ensure good sample recovery. The soil samples collected will be removed from the sampler and split lengthwise. One-half of the sample will be placed on clean aluminum foil for lithologic logging. The other half of the sample will be placed in analyte-appropriate sample containers (Appendix A) and shipped to the analytical laboratory for analysis of BTEX, total organic carbon (TOC), moisture content, and total petroleum hydrocarbons (TPH).

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.3. The descriptive log will contain:

- Sample interval (top and bottom depth);

- Sample recovery;
- Presence or absence of contamination;
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Depths of lithologic contacts and/or significant textural changes will be measured and recorded to the nearest 0.1 foot.

Soil coring is intended to verify/validate the CPT/LIF data. Limited site-specific hydrogeologic characterization of Sites OT-41 and SS-42 has already been accomplished.

3.1.3 CPT Locations and Datum Survey

Sample location and other relevant site information for the soil cores will be recorded by the Parsons ES field scientist. The horizontal location of all CPT/LIF testing locations relative to established Base coordinates will be measured by a surveyor. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface will also be measured. Elevations will be measured to the nearest 0.1 foot relative to USGS mean sea level data.

3.1.4 Site Restoration

After sampling is complete, each CPT site will be restored to as closely to its original condition as possible. Holes created by CPT in sandy soils similar to those found at the Base tend to cave in soon after extraction of the penetrometer rod. However, any test holes remaining open after extraction of the penetrometer rod will be sealed with bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the ground water.

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: ______ CONTRACTOR: ______ DATE SPUD: ______
CLIENT: AFCEE RIG TYPE: ______ DATE CMPL.: ______
JOB NO.: 722450.12 DRLG METHOD: ______ ELEVATION: ______
LOCATION: Wurtsmith AFB BORING DIA.: ______ TEMP: ______
GEOLOGIST: ______ DRLG FLUID: ______ WEATHER: ______
COMENTS: ______

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1											
	5											
	10											
	15											
	20											
	25											
	30											
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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3.1.5 Equipment Decontamination Procedures

The CPT push rods will be cleaned with the USACE CPT steam-cleaning system (rod cleaner) as the rods are withdrawn from the ground. A vacuum system, which results in nearly 100-percent recovery of steam-cleaning rinseate from the rod cleaner, located beneath the CPT truck will be used. Rinseate is generated only as the rods move past the cleaner, thereby minimizing liquid waste generation. Care will be taken not to apply the pressurized steam to the LIF module. If free product is encountered, the rinseate will be collected in 55-gallon drums. Filled 55-gallon drums will be stored at the Base, and Base personnel will arrange for final disposal of the drums and their contents. Base personnel are responsible for sampling the contents of the drums to identify any hazardous constituents before the drums are transported to an appropriate disposal facility. If free product is not encountered, rinseate will be disposed of at each CPT/LIF location by disposing of it on the ground surface near the CPT/LIF location..

Prior to arriving at the site, and between each monitoring point site, instrumented probes, tips, sleeves, pushrods, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination. All rinseate will be collected in 55-gallon drums and later transported and disposed of by the Base personnel .

Potable water to be used in CPT equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

3.2 PERMANENT MONITORING POINT INSTALLATION

To further characterize the hydrogeologic conditions of the shallow subsurface, up to 32 new ground water monitoring points will be installed at Sites OT-41 and SS-42. The following sections describe the proposed monitoring point locations and completion intervals, monitoring point installation, monitoring point development, and equipment decontamination procedures.

3.2.1 Monitoring Point Locations and Completion Intervals

The proposed locations for up to 32 new monitoring points were determined from a review of existing data gathered during RI activities conducted under the Base's IRP (ICF, 1994). The final locations for these monitoring points will be based on field observations. The necessity for additional monitoring points results from the lack of strategically placed downgradient monitoring points relative to contamination identified at the site.

Nine nests of two monitoring points will be installed within the plume and downgradient of contamination east of Site SS-42. Five nests of monitoring points will be placed downgradient of Site OT-41. A single monitoring point nest will be installed upgradient of each site to provide a source of information on background contaminant concentrations and geochemical parameters, as well as to provide additional ground water flow direction information. Proposed monitoring points are shown on Figure 3.2. The monitoring point locations were selected to provide useful hydrogeologic data necessary for successful implementation of the Bioplume II model and to monitor potential fuel hydrocarbon migration from the site. Locations may change as field data dictate.

Each monitoring point nest will consist of a pair of monitoring points: a shallow point intended to sample the shallow portion of the aquifer at or near the water table, and a deep point intended to sample the ground water in the lower portion of the unconfined aquifer. The shallow screened intervals will extend from about 1 foot above the water table to about 2 feet below the water table. The deep points will be placed based on contaminant distribution. All monitoring points will be installed with 1 meter of screen. The proposed screened intervals will help mitigate the dilution of water samples from potential vertical mixing of contaminated and uncontaminated ground water in the monitoring point casing, and will give three-dimensional information on the nature of vertical and horizontal hydraulic gradients in the area. Adjustments to the depth and length of the screened interval of the monitoring points may be necessary in response to actual aquifer conditions and contaminant distributions identified during CPT/ LIF testing.

3.2.2 Monitoring Point Installation Procedures

This section describes the procedures to be used for installation of new ground water monitoring points. All new monitoring points will be constructed of 0.75-inch OD /0.5-inch ID polyvinyl chloride (PVC) casing placed with a CPT pushrod using equipment described in Section 3.1.

3.2.2.1 Pre-Placement Activities

All necessary digging, coring, drilling, and ground water monitoring point installation permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed drilling locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 3.1.1.

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

3.2.2.2 Ground Water Monitoring Point Installation

3.2.2.2.1 Monitoring Point Materials Decontamination

Monitoring point completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, casing, screen, and casing plugs and caps will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used.

3.2.2.2.2 Monitoring Point Screen and Casing

Ground water monitoring points will be installed by attaching 0.75-inch OD PVC screen to the sacrificial tip of the pushrod of the penetrometer device and then inserting the penetrometer cone into the subsurface. As the pushrod descends, new PVC casing will be continuously attached until the desired depth is reached and a fully cased

monitoring point is created. Data collection devices such as CPT and LIF will not be used during monitoring point placement.

Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4). This information will become part of the permanent field record for the site.

Monitoring point screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 0.5 inch. The screens will be factory slotted with 0.01-inch openings. The positions of the screens will be selected by the field scientist after consideration is given to the geometry and hydraulic characteristics of the stratum in which the monitoring point will be screened. The shallow screens (described in Section 3.2.1) will be placed to sample at or near the water table, and the deep screens will be placed to sample below the water table in order to determine vertical gradients and vertical contaminant distribution.

Blank monitoring point casing will be constructed of Schedule 40 PVC with an ID of 0.5 inch. All monitoring point casing sections will be flush-threaded; joints will not be glued. The casing at each monitoring point will be fitted with a bottom cap and a top cap constructed of PVC. The top cap will be vented to maintain ambient atmospheric pressure within the monitoring point casing, unless it is neccessary to complete the well covers at-grade.

The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

MONITORING POINT INSTALLATION RECORD

JOB NAME WURTSMITH AIR FORCE BASE MONITORING POINT NUMBER ______

JOB NUMBER 722450.12 INSTALLATION DATE ______ LOCATION ______

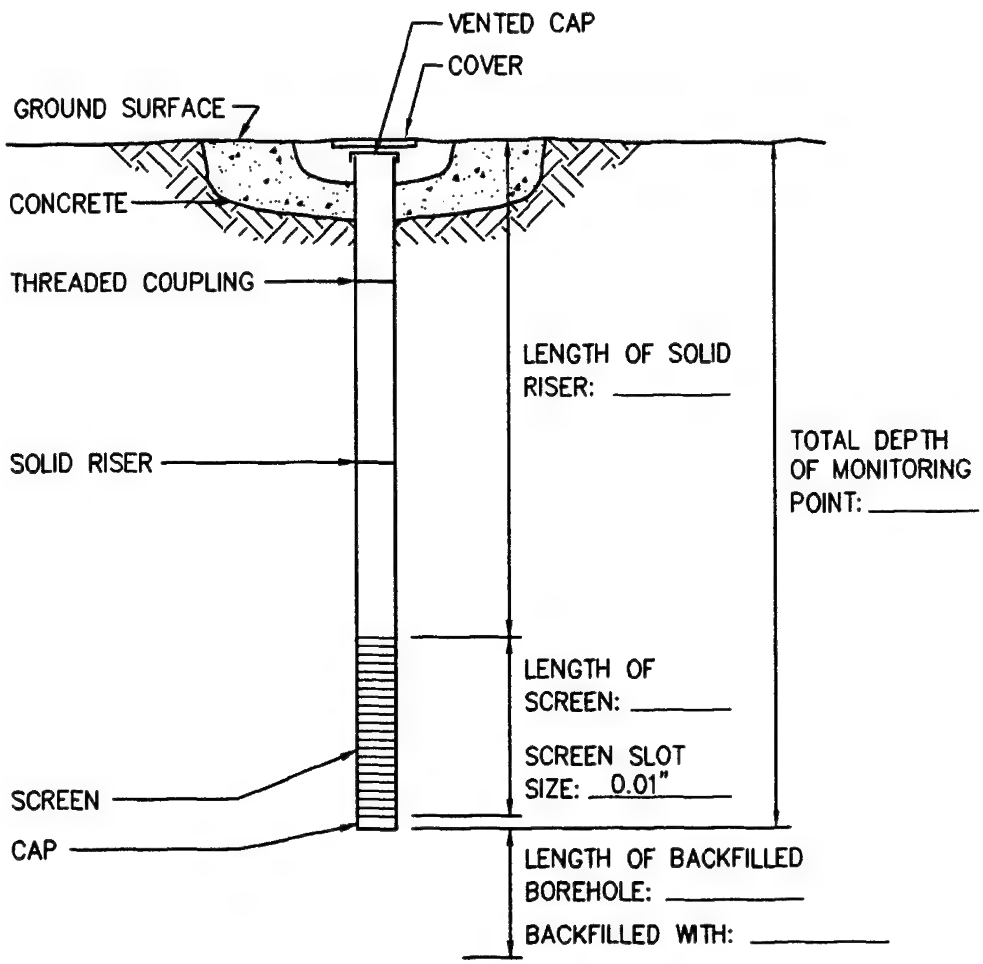
DATUM ELEVATION ______ GROUND SURFACE ELEVATION ______

DATUM FOR WATER LEVEL MEASUREMENT ______

SCREEN DIAMETER & MATERIAL ______ SLOT SIZE ______

RISER DIAMETER & MATERIAL ______ BOREHOLE DIAMETER ______

CONE PENETROMETER CONTRACTOR ______ ES REPRESENTATIVE ______



(NOT TO SCALE)

STABILIZED WATER LEVEL ______ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH ______ FEET BELOW DATUM.

GROUND SURFACE ______ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

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Denver, Colorado

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3.2.2.2.3 Above-Grade and At-Grade Well Completion

Each monitoring point will be completed with an at-grade protective cover or an above-grade protector pipe. In areas where pavement is present, the at-grade cover will be cemented in place using concrete blended to the existing pavement. The concrete immediately surrounding the monitoring point will be sloped gently away from the protective casing to facilitate runoff during precipitation events. In areas where pavement is not present, a steel protector post will be installed around the well point riser in order to protect the riser from damage. Each post will be painted orange and cemented into a 1-foot-square pad to ensure the stability of the post.

3.2.2.4 Monitoring Point Development

The new monitoring points will be developed prior to sampling. Development removes sediment from inside the monitoring point casing and flushes fines from the portion of the formation adjacent to the monitoring point screen.

Monitoring point development will be accomplished using a peristaltic pump with polyethylene tubing or a Waterra® inertial pump consisting of a 10-millimeter (mm) check valve fitted with 3/8-inch high-density polyethylene (HDPE) tubing. The pump will be used to surge the well and will be regularly lowered to the bottom of the monitoring point so fines that have accumulated in the bottom are agitated and removed from the monitoring point.

Development will be continued until a minimum of 10 casing volumes of water has been removed from the monitoring point and until pH, temperature, specific conductivity, DO, and water clarity (turbidity) stabilize. If the water remains turbid, monitoring point development will continue until the turbidity of the water produced has been stable after the removal of several casing volumes.

Development waters will be disposed of at the location of each well by applying the water to the ground surface by the well. If free product is encountered, development water will be collected in 55-gallon drums provided by Parsons ES. Filled 55-gallon drums will be placed on pallets and transported by Base personnel to the Base's designated hazardous waste collection area.

3.2.2.5 Monitoring Point Development Records

A monitoring point development record will be maintained for each point. The monitoring point development record will be completed in the field by the field scientist. Figure 3.5 is an example of the monitoring point development record. Development records will include:

- Monitoring point number;
- Date and time of development;
- Development method;
- Predevelopment water level and monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Postdevelopment water level and monitoring point depth; and
- Field analytical measurements, including pH and specific conductivity.

3.2.2.6 Water Level Measurements

Water levels at monitoring wells and newly installed monitoring points will be measured within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe.

3.2.2.7 Monitoring Point Location and Datum Survey

The locations and elevations of the new monitoring points will be surveyed soon after point completion. The horizontal location will be measured relative to established Base coordinates. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface adjacent to the monitoring point casing and the measurement datum elevation (top of PVC casing) will be measured relative to the USGS mean sea level datum. The ground surface elevation will be measured to the nearest 0.1 foot and the elevation of the measurement datum, outer casing, and surveyor's pin (if present) will be measured to the nearest 0.01 foot.

MONITORING POINT DEVELOPMENT RECORD

Page__ of__

Job Number: ______________________ Job Name: ______________________

Location ______________________ By______________________ Date________.

Well Number______________________ Measurement Datum______________________

Pre-Development Information Time (Start):

Water Level: Total Depth of Well:

Water Characteristics

Color______________________ Clear Cloudy

Odor: None Weak Moderate Strong

Any Films or Immiscible Material______________________

pH__________ Temperature(^{o}F ^{o}C) __________

Specific Conductance(μS/cm)______________________

Interim Water Characteristics

Gallons Removed

pH

Temperature (^{o}F ^{o}C)

Specific Conductance(μS/cm)

Post-Development Information Time (Finish):

Water Level: Total Depth of Well:

Approximate Volume Removed:

Water Characteristics

Color______________________ Clear Cloudy

Odor: None Weak Moderate Strong

Any Films or Immiscible Material______________________

pH__________ Temperature(^{o}F ^{o}C) __________

Specific Conductance(μS/cm)______________________

Comments:

FIGURE 3.5

MONITORING POINT DEVELOPMENT RECORD

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

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3.2.3 Site Restoration

After monitoring point installation and sampling is complete, each site will be restored as closely as possible to its original condition. Contaminated development waters and sampling purge waters will be stored in 55-gallon drums and transported by Base personnel to the designated area used for collection of hazardous wastes at the Base.

3.3 GROUND WATER SAMPLING

This section describes the scope of work required for collection of ground water quality samples at existing ground water monitoring wells, newly installed monitoring points, and at holes punched with modified cone penetrometer equipment. It is anticipated that a peristaltic pump with disposable high density polyethylene (HDPE) tubing will be used to collect ground water samples. If sampling with a peristaltic pump and disposable HDPE tubing, is not possible due to excessive depth to ground water, ground water samples will be obtained using a Waterra® inertial pump, or disposable bailers. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians from Parsons ES and the USEPA Robert S. Kerr Research Lab (USEPA RSKERL) who are trained in the conduct of ground water sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available on site for reference.

The ground water sampling process described in Section 3.3.1 will occur between June 19 and July 2, 1995. Activities that will occur during ground water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well/point integrity including:
    - Protective cover, cap, and lock,
    - External surface seal and pad,

- Monitoring point stick-up, cap, and datum reference, and
- Internal surface seal;
- Ground water sampling, including
  - Water level and product thickness measurements,
  - Visual inspection of sample water,
  - Monitoring point casing evacuation, and
  - Sample collection;
- Sample preservation and shipment, including
  - Sample preparation,
  - Onsite measurement of physical parameters, and
  - Sample labeling;
- Completion of sampling records; and
- Sample disposition.

Detailed ground water sampling and sample handling procedures are presented in following sections.

3.3.1 Ground Water Sampling Strategy

Ground water samples will be collected from previously installed monitoring wells and newly installed ground water monitoring points. Ground water samples may also be collected at several locations using a modified CPT procedure that allows discrete ground water samples to be collected.

3.3.1.1 Monitoring Well and Monitoring Point Sampling Locations

Ground water sampling locations, including monitoring wells and CPT locations, are shown on Figure 3.2

3.3.1.2 Modified CPT Ground Water Sampling Locations

Ground water samples may be collected using modified CPT equipment at some or all of the proposed CPT/LIF locations shown in Figure 3.2. The number of locations sampled using the modified CPT equipment is dependent on the success of installing monitoring points with the USACE CPT and the feasibility of sampling monitoring point using a peristaltic pump. The methods to be used to sample ground water at these locations are described in Section 3.3.3.2. Not all proposed CPT locations will serve as ground water sampling sites. Locations to be sampled will be recommended by the field scientist directing the contaminant plume delineation efforts described in Section 3.1.1. Sampling locations will be placed in areas where the suspected edges of the dissolved-phase and free-phase product plumes are located. It may be necessary to collect all 32 ground water samples at Sites OT-41 and SS-42 using this method if permanent monitoring point installation is not possible.

3.3.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.3.2.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the CPT tool, water level probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with isopropyl alcohol or commercial-grade acetone;

- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the Ground water Sampling Record (Figure 3.6).

If precleaned, disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the USEPA mobile laboratory's permanent record of the sampling event.

3.3.2.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of DO, carbon dioxide, pH, electrical conductivity, temperature, reduction/oxidation (redox) potential, sulfate, nitrate, and ferrous iron (Fe^{2+}).

3.3.3 Sampling Procedures

Special care will be taken to prevent contamination of the ground water and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and through cross-contamination due to insufficient cleaning of equipment between wells and monitoring points. To prevent such contamination, the water level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.2.2.1. Also, the Waterra® inertial pump or the peristaltic pump and HDPE tubing will be thoroughly cleaned with acetone and distilled water before use at each new and existing sampling point. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile or latex gloves will be worn each time a different well or monitoring point is sampled. Dedicated, disposable bailers may be used on the 2-inch ID existing wells. A new bailer will be used at each well. The following paragraphs present the procedures to be followed for ground water sample collection from ground water monitoring wells and monitoring points. These activities will be performed in the order

SAMPLING LOCATION ____________
SAMPLING DATE(S) ____________

GROUND WATER SAMPLING RECORD - MONITORING WELL ____________
(number)

REASON FOR SAMPLING: [ ] Regular Sampling; [ ] Special Sampling;
DATE AND TIME OF SAMPLING: ____________, 19___ ________ a.m./p.m.
SAMPLE COLLECTED BY: ____________ of ____________
WEATHER: ____________
DATUM FOR WATER DEPTH MEASUREMENT (Describe): ____________

MONITORING WELL CONDITION:
[ ] LOCKED: [ ] UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS: ____________
INNER PVC CASING CONDITION IS: ____________
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
[ ] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
[ ] MONITORING WELL REQUIRED REPAIR (describe): ____________

Check-off

1 [ ] EQUIPMENT CLEANED BEFORE USE WITH ____________
Items Cleaned (List): ____________

2 [ ] PRODUCT DEPTH ____________ FT. BELOW DATUM
Measured with: ____________

WATER DEPTH ____________ FT. BELOW DATUM
Measured with: ____________

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: ____________
Odor: ____________
Other Comments: ____________

4 [ ] WELL EVACUATION:
Method: ____________
Volume Removed: ____________
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: ____________
Other comments: ____________

FIGURE 3.6

GROUND WATER SAMPLING RECORD

Sites OT-41 and SS-42
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Ground Water Sampling Record - Monitoring Well No. ________________ (Cont'd)

5 [ ] SAMPLE EXTRACTION METHOD:

[ ] Bailer made of: ________________
[ ] Pump, type: _
[ ] Other, describe: ________________

Sample obtained is [ ] GRAB; [ ] COMPOSITE SAMPLE

6 [ ] ON-SITE MEASUREMENTS:

Temp: ________ ° _____	Measured with: ________________
pH: ________________	Measured with: ________________
Conductivity: ________	Measured with: ________________
Dissolved Oxygen: ________	Measured with: ________________
Redox Potential: ________	Measured with: ________________
Salinity: ________	Measured with: ________________
Nitrate: ________	Measured with: ________________
Sulfate: ________	Measured with: ________________
Ferrous Iron: ________	Measured with: ________________
Other: ________________	

7 [ ] SAMPLE CONTAINERS (material, number, size): ________________

8 [ ] ON-SITE SAMPLE TREATMENT:

[ ] Filtration:

Method ________	Containers: ________
Method ________	Containers: ________
Method ________	Containers: ________

[ ] Preservatives added:

Method ________	Containers: ________
Method ________	Containers: ________
Method ________	Containers: ________
Method ________	Containers: ________

9 [ ] CONTAINER HANDLING:

[ ] Container Sides Labeled
[ ] Container Lids Taped
[ ] Containers Placed in Ice Chest

10 [ ] OTHER COMMENTS: ________________

FIGURE 3.6 (Continued)

GROUND WATER SAMPLING RECORD

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

presented below. Exceptions to this procedure will be noted in the field scientist's field notebook.

3.3.3.1 Ground Water Monitoring Well and Monitoring Point Sampling

3.3.3.1.1 Preparation of Location

Prior to starting the sampling procedure, the area around the existing wells and new monitoring points will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well/point.

3.3.3.1.2 Water Level and Total Depth Measurements

Prior to removing any water from the monitoring well or monitoring point, the static water level will be measured. An electric water level probe will be used to measure the depth to ground water below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring well/point and the depth will be measured to the nearest 0.01 foot. Based on these measurements, the volume of water to be purged from the monitoring well/point will be calculated. If free-phase product is encountered, the thickness of the product will be measured.

3.3.3.1.3 Monitoring Well/Point Purging

Three times the calculated casing volume will be removed from the well/point. All purge water will be disposed of at the monitoring well/point location. If free product is encountered, the contaminated purge water will be placed in 55-gallon drums and disposed of by Base personnel. If free product is not encountered, purge water will be disposed of immediately at the site by application to the ground surface by the well. Emptied 55-gallon drums will be handled by Base personnel. A peristaltic pump or a Waterra® inertial pump will be used for new monitoring point purging. A peristaltic pump or a dedicated, disposable bailer will be used to purge the existing wells, depending on the depth, diameter, and screened interval of the well.

If a monitoring well/point is evacuated to a dry state during purging, the monitoring well/point will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring well/point to obtain the necessary sample quantity. Sample compositing, or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

3.3.3.1.4 Sample Extraction

A peristaltic pump or a Waterra® inertial pump with HDPE tubing will be utilized to extract ground water samples from the new monitoring well/points. A dedicated, disposable bailer will be used to sample the existing 2-inch ID wells or a peristaltic pump with HPDE tubing. The pump or bailer will be lowered through the casing into the water gently to prevent splashing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the USEPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be disposed of at the sampling location. If free product is encountered, the water from that sampling will be placed into the 55-gallon drums used for monitoring well/point purge waters and transported to the facilities provided on the Base for disposal by Base personnel.

3.3.3.2 Modified CPT Sampling

3.3.3.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the penetrometer insertion point will be cleared of foreign materials, such as brush, rocks, or debris. This will prevent sampling equipment from inadvertently contacting foreign materials near the sampling point.

3.3.3.2.2 Sampling Interval and Method

The sampling depth and interval will be specified prior to driving the CPT pushrod into the ground. The Parsons ES field scientist will verify the sampling depth by measuring the length of each pushrod prior to insertion into the ground. A disposable drive tip fitted with a Teflon® screen will be placed on the tip of the pushrod, and the rod will be pushed into the ground using the same truck, frames, and hydraulic equipment described in Section 3.1. After reaching the desired depth, the penetrometer pushrod will be raised 1 to 3 feet to allow decoupling of the disposable drive tip and to allow water to percolate into the end of the hollow pushrod. Water samples will be collected from water entering the downhole, open end of the pushrod through the Teflon® screen using a 0.75-inch Teflon® bailer, a Waterra® inertial pump or a peristaltic pump. The ground water sample will be acquired as described in Section 3.3.3.2.4.

3.3.3.2.3 Water Level and Total Depth Measurements

Prior to removing any water from the modified CPT sample location, the static water level will be measured. An electric water level probe will be inserted into the pushrod until it confirms that ground water has been reached.

3.3.3.2.4 Sample Extraction

A 0.75-inch Teflon® bailer, Waterra® inertial pump, or a peristaltic pump will be used to extract ground water samples from the modified CPT sampling locations. Prior to sample collection, ground water will be purged until dissolved oxygen and temperature readings have stabilized. The sample will be transferred directly to the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the USEPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be disposed of at the sampling location. If free product is encountered, the water from that sampling location will be placed into the 55-gallon drums used for monitoring well/point purge waters and transported for disposal by Base personnel to the facilities provided on the Base.

3.3.4 Onsite Ground Water Parameter Measurement

As indicated on Table 3.1, many of the ground water chemical parameters will be measured onsite by USEPA RSKERL staff. Some of the measurements will be made with direct-reading meters, while others will be made using a HACH® portable colorimeter in accordance with specific HACH® analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of Alconox® and water, and rinsing with deionized water and ethanol to prevent interference or cross contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric method, the analysis will be repeated by diluting the ground water sample with double-distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during ground water analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled as to their contents and carefully stored for later transfer to the approved disposal facility by Base personnel.

3.3.4.1 Dissolved Oxygen Measurements

DO measurements will be made before and immediately following ground water sample acquisition using a meter with a downhole oxygen sensor or a sensor in a flow-through cell. When DO measurements are taken in monitoring wells/points that have not yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize.

3.3.4.2 pH, Temperature, and Specific Conductance

The pH, temperature, and specific conductance of a ground water sample can change significantly within a short time following sample acquisition. To minimize the effect of any changes, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analysis. The measurements will be made in a clean glass container separate from those

intended for laboratory analysis, and the measured values will be recorded in the ground water sampling record (Figure 3.6).

3.3.4.3 Carbon Dioxide Measurements

RSKERL scientists will measure carbon dioxide concentrations in ground water via titrimetric analysis using HACH® Method 8223 (0-250 mg/L as CO_2). Sample preparation and disposal procedures are the same as outlined at the beginning of Section 3.3.4.

3.3.4.4 Alkalinity Measurements

Alkalinity in ground water helps buffer the ground water system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the ground water sample will be measured in the field by experienced RSKERL scientists via titrimetric analysis using USEPA-approved HACH® Method 8221 (0-5,000 mg/L as $CaCO_3$).

3.3.4.5 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or ground water conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in ground water will be measured in the field by experienced RSKERL scientists via colorimetric analysis using a HACH® DR/700 Portable Colorimeter. Nitrate concentrations in ground water samples will be analyzed after preparation with HACH® Method 8039 (0-30.0 mg/L NO_3). Nitrite concentrations in ground water samples will be analyzed after preparation with USEPA-approved HACH® Method 8507 (0-0.35 mg/L NO_2).

3.3.4.6 Sulfate and Sulfide Sulfur Measurements

Sulfate in ground water is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is the product of sulfate reduction. The RSKERL scientist will measure sulfate and sulfide concentrations via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. USEPA-approved HACH® Methods 8051 (0-70.0 mg/L SO_4) and 8131 (0.60 mg/L S^{2-}) will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively.

3.3.4.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the oxidation/reduction potential of the ground water and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. HACH® Method 8008 for total soluble iron (0-3.0 mg/L Fe^{3+} + Fe^{2+}) and HACH® Method 8146 for ferrous iron (0-3.0 mg/L Fe^{2+}) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.4.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a HACH® DR/700 Portable Colorimeter. USEPA approved HACH® Method 8034 (0-20.0 mg/L) will be used to prepare the samples for quantitation of manganese concentrations. Sample preparation and disposal procedures are outlined earlier in Section 3.3.4.

3.4 SAMPLE HANDLING FOR LABORATORY ANALYSIS

This section describes the handling of samples from the time of sampling until the samples are delivered to the EPA mobile laboratory.

3.4.1 Sample Preservation

The USEPA laboratory support personnel will add any necessary chemical preservatives prior to filling the sample containers. Samples will be prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4 degrees centigrade (°C). Samples will be promptly delivered to the USEPA laboratory personnel, who will be responsible for shipment of appropriate samples to the RSKERL in Ada, Oklahoma for analysis.

3.4.2 Sample Containers and Labels

Sample containers and appropriate container lids will be provided by the USEPA mobile laboratory (see Appendix A). The sample containers will be filled as described in Section 3.3.3.2.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., ground water);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the onsite EPA mobile laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;

- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by hand to the USEPA mobile laboratory. Delivery will occur as soon as possible after sample acquisition.

3.4.4 Chain-of-Custody Control

Chain-of-custody documentation for the shipment of samples from the USEPA mobile laboratory to the USEPA RSKERL analytical laboratory in Ada, Oklahoma, will be the responsibility of the USEPA RSKERL and USEPA RSKERL field personnel.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance, and
  - Sample odor;
- Weather conditions;
- Water level prior to purging (ground water samples only);
- Total monitoring well/point depth (ground water samples only);
- Sample depth (soil samples only);
- Purge volume (ground water samples only);

- Water level after purging (ground water samples only);
- Monitoring well/point condition (ground water samples only);
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity (ground water samples only); and
- Any other relevant information.

Ground water sampling information will be recorded on a ground water sampling form. Figure 3.6 shows an example of the ground water sampling record. Soil sampling information will be recorded in the field log book.

3.4.6 Laboratory Analyses

Laboratory analyses will be performed on all ground water and soil samples as well as the QA/QC samples described in Section 5. The analytical methods to be used for this sampling event are listed in Table 3.1. Prior to sampling, USEPA RSKERL personnel will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with USEPA protocol or those reported in Appendix A of this plan.

USEPA RSKERL laboratory support personnel will specify the necessary QC samples and prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory. Containers, ice chests with adequate padding, and cooling media will be provided by USEPA RSKERL laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the mobile laboratory.

3.5 AQUIFER TESTING

Slug tests will be conducted on selected existing wells to estimate the hydraulic conductivity of the glacial deposits at Sites OT-41 and SS-42. This information is required to accurately estimate the velocity of ground water and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug

tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test; for Sites OT-41 and SS-42, both methods will be used in sequence.

3.5.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test.** Two types of testing are possible: rising head and falling head test. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.5.2 Equipment

The following equipment is needed to conduct a slug test:

- Teflon®, PVC, or metal slugs;

- One-quarter-inch nylon or polypropylene rope;
- Electric water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data recording instrument (such as the Terra Model SDEE-03CD, or equiivalent).

3.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Because hydraulic testing will be completed on existing wells, it will be assumed that the wells were properly developed and that water levels have stabilized. Slug testing will proceed only after water level measurements show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results. The field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.2.2.2.

3.5.4 Falling Head Test

The falling head test is the first step in the two-step slug-testing procedure. The following steps describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.

2. Open the well. Where wells are equipped with water tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.

3. Prepare the Aquifer Slug Test Data Form (Figure 3.7) with entries for:

   - Borehole/well number,
   - Project number,
   - Project name,
   - Aquifer testing team,
   - Climatic data,
   - Ground surface elevation,
   - Top of well casing elevation,
   - Identification of measuring equipment being used,
   - Page number,
   - Static water level,
   - Date, and
   - Time intervals (0, 1, 3, 5, 7, 9, 10, and 12 minutes and every 3 minutes thereafter through 60 elapsed minutes, then in 10-minute intervals for the next hour, and in 30-minute intervals for the next 3 hours).

4. Measure the static water level in the well to the nearest 0.01 foot.

5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.

6. Lower the decontaminated slug into the well to just above the water level in the well.

7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.

8. Terminate data recording when the water level stabilizes in the well.

3.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.

2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.

3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using the method of Hvorslev (1951) for confined aquifers or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The standard slug test form (Figure 3.8) is based on equations and test methods developed by Hvorslev (1951). Figure 3.9 is the Bouwer and Rice Analysis Data Form. Figure 3.10 contains the dimensionless parameters A, B, and C used for the Bouwer and Rice Analysis.

Aquifer Slug Test Data Sheet

Location________________ Client________________ Well No.__________

Job No. ________________ Field Scientist____________ Date__________

Water Level________________ Total Well

Depth________________________

Measuring Datum____________ Elevation of Datum____________________

Weather________________ Temp____________________________

Comments____

Beginning Time	Ending Time	Initial Head Reading	Ending Head Reading	Test Type (Rise/Fall)	File Name	Comments

FIGURE 3.7

AQUIFER TEST DATA FORM

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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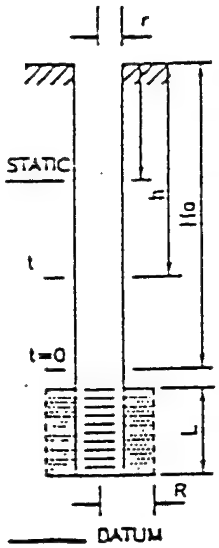
HVORSLEV'S METHOD FOR K

PROJECT ______________ LOCATION ______________
WELL NUMBER ______________ ELEVATION ______________
DATE ______________



STATIC HEAD ______

PIPE RADIUS (r) ______

BORE HOLE RADIUS (R) ______

SATURATED SCREEN LENGTH (L) ______

HYDRAULIC CONDUCTIVITY:

$$K = \frac{r^2 \ln(L/R)}{2 L T_o}$$

K= ______________

TIME (MIN)	WATER DEPTH (FT)	RECOVERY TO STATIC ±(WATER DEPTH−STAT)	$\frac{h}{Ho}$
STATIC		—	—
00		(Ho)	1.00
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	
		(h)	

K= ________ FT/MIN K= ________ FT/DAY K= ________ CM/SEC

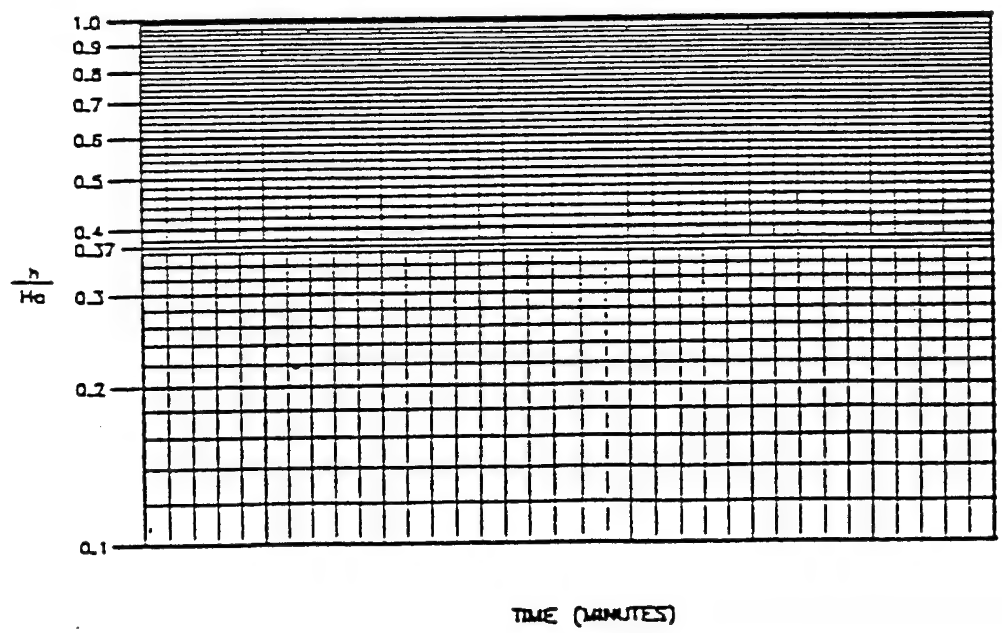


FIGURE 3.8

SLUG TEST FORM/ HVORSLEV ANALYSIS

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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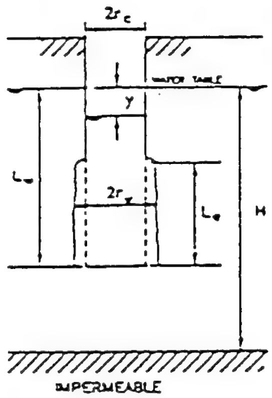
BOUWER AND RICE METHOD FOR K

(Reference: GROUNDWATER – May, June 1989, Vol. 27, No. 3)

PROJECT ____________ LOCATION ____________

WELL NUMBER ____________ ELEVATION ____________

DATE ____________



STATIC HEAD ______

PIPE RADIUS (r_c) ______

BORE HOLE RADIUS (r_w) ______

SATURATED SCREEN LENGTH (L_e) ______

WELL DEPTH ______

HYDRAULIC CONDUCTIVITY:
(ASSUME $L_w = H$)

$$K = \frac{(r_c^2)\ln(R_e/r_w)}{2L_e}\left[\frac{1}{t}\right]\ln\left[\frac{y_0}{y_t}\right]$$

K= ____________

TIME (MIN)	WATER DEPTH (FT)	y_t (WATER DEPTH–STAT)
STATIC		______
∞		

K= ________ FT/MIN K= ________ FT/DAY K= ________ CM/SEC

WHERE: $*r_c = [(1-n)r_c^2 + nr_w^2]$
n = POROSITY (~30%)

* r_c TAKES INTO ACCOUNT THE RADIUS OF THE WELL AND THE THICKNESS AND POROSITY OF THE GRAVEL PACK. POROSITY OF THE GRAVEL PACK (n) IS ESTIMATED AT 30%. USE THIS EQUATION IF A GRAVEL PACK IS PRESENT.

ASSUME $L_w = H$: $$\ln\frac{R_e}{r_w} = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{C}{(L_e/r_w)}\right]^{-1} \quad C = 1.4$$

ASSUME $L_w < H$: $$\ln\frac{R_e}{r_w} = \left[\frac{1.1}{\ln(L_w/r_w)} + \frac{A + B\ln[(H-L_w)/r_w]}{(L_e/r_w)}\right]^{-1}$$

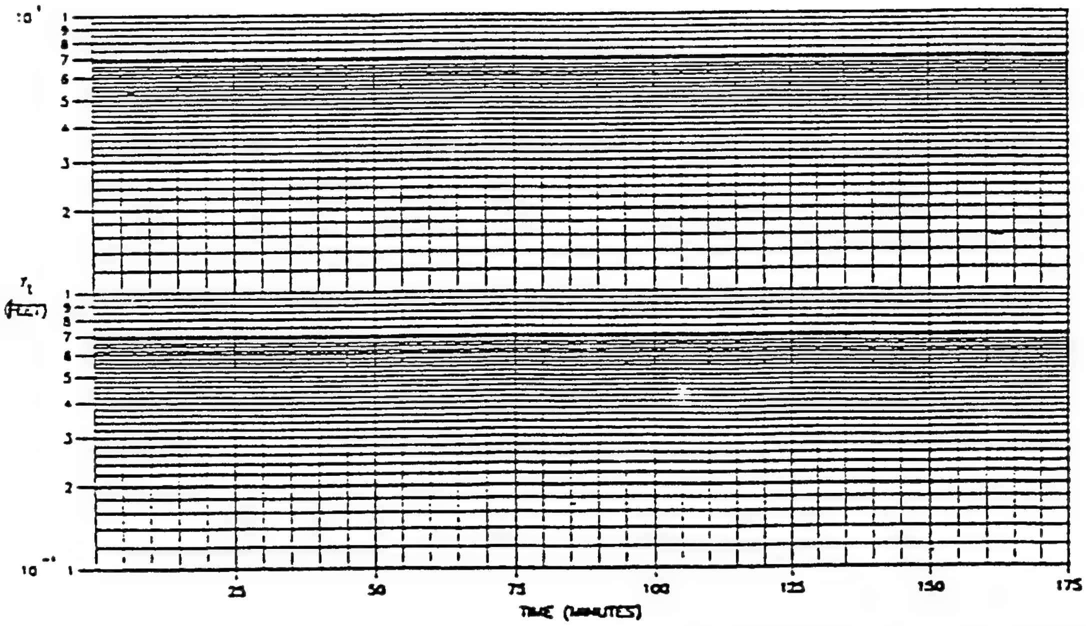


FIGURE 3.9

BOUWER AND RICE ANALYSIS DATA FORM

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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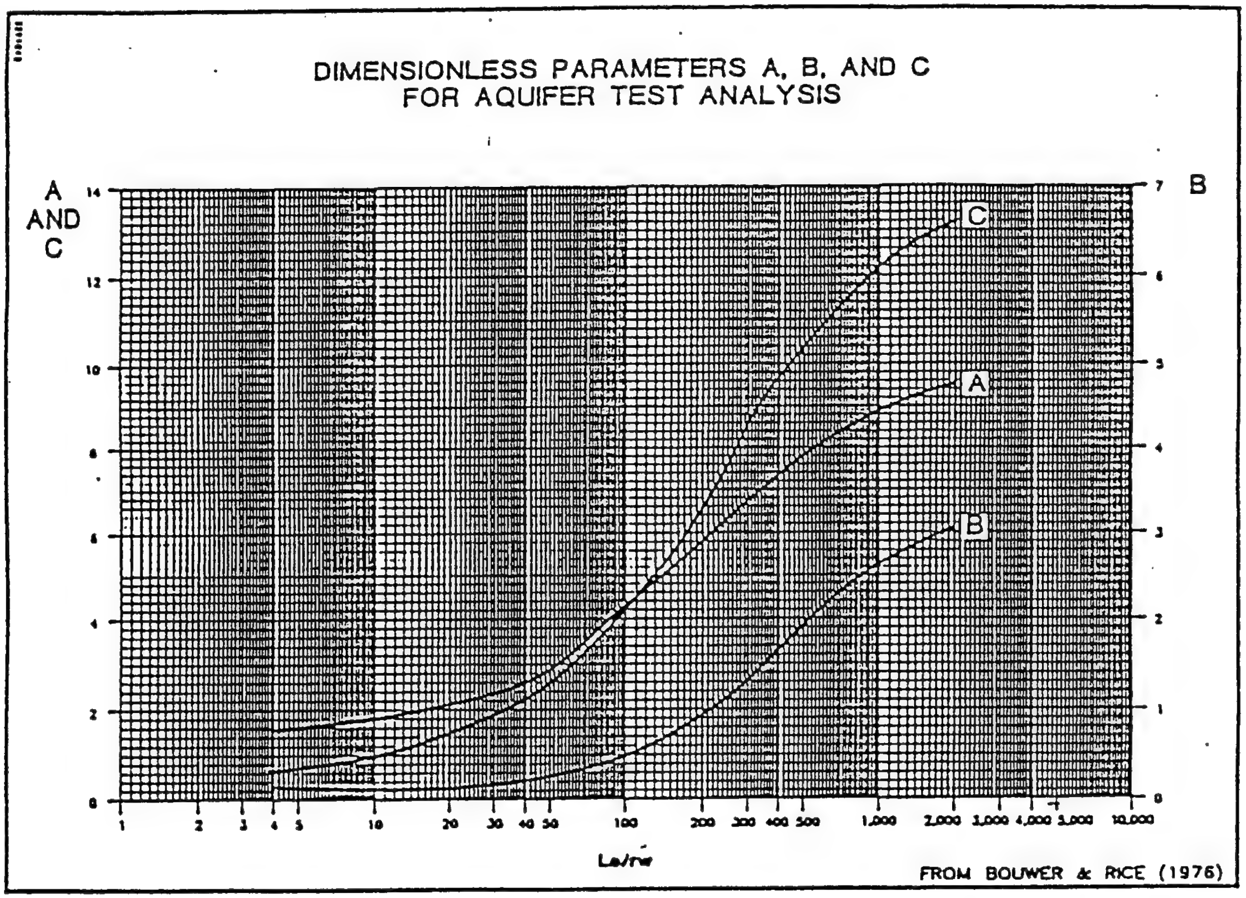

FIGURE 3.10

DIMENSIONLESS PARAMETERS

Sites OT-41 and SS-42
Intrinsic Remediation TS
Wurtsmith Air Force Base
Oscoda, Michigan

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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SECTION 4

REMEDIAL OPTION EVALUATION AND TS REPORT

Upon completion of field work, the Bioplume II numerical ground water model will be used to determine the fate and transport of fuel hydrocarbons in ground water at Sites OT-41 and SS-42. Based upon model predictions of contaminant concentration and distribution through time, and upon potential exposure pathways, the potential risk to human health and the environment will be assessed. If it is shown that intrinsic remediation of BTEX compounds at Sites OT-41 and SS-42 is sufficient to reduce the potential risk to human health and the environment to acceptable levels, Parsons ES will recommend implementation of the intrinsic remediation option. If intrinsic remediation is chosen, Parsons ES will prepare a site-specific, long-term monitoring plan that will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation option is deemed inappropriate for use at this site, institutional controls such as ground water or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are inappropriate, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial options will be recommended. Potential remedial options include, but are not limited to, free-product recovery, ground water pump-and-treat, enhanced biological treatment, bioventing, and air sparging. The reduction in dissolved BTEX that should result from remedial activities will be used to produce a new input file for the Bioplume II model. The model will then be used to predict the BTEX plume (and risk) reduction that should result from remedial actions.

Upon completion of Bioplume II modeling and remedial option selection, an TS report detailing the results of the modeling and remedial option selection will be prepared. This report will follow the outline presented in Table 4.1 and will contain an introduction, a description of site characterization activities, a discussion of soil and ground water

contaminants identified, a discussion of the ground water modeling effort, the identification of remediation objectives, a description of remediation alternatives, an analysis of remediation alternatives, and the recommended remedial approach. This report will also contain the results of the site characterization activities described herein and a description of the Bioplume II model developed for this site.

TABLE 4.1
EXAMPLE TS REPORT OUTLINE
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

EXECUTIVE SUMMARY

INTRODUCTION

- SCOPE AND OBJECTIVES
- FACILITY BACKGROUND
    - Operational History
    - Current Remedial Activities

SITE CHARACTERIZATION ACTIVITIES

- CONE PENETROMETRY, MONITORING POINT INSTALLATION, AND SOIL SAMPLING ACTIVITIES
    - CPT and Ground Water Monitoring Point Locations
    - Ground Water Monitoring Point Installation Procedures
    - Soil Sampling
- GROUND WATER SAMPLING
    - Ground Water Sampling Locations
    - Preparation for Sampling
    - Sampling Procedures
    - Onsite Chemical Parameter Measurement
    - Sample Handling
- AQUIFER TESTING
    - Slug Testing
    - Slug Test Data Analysis
- PHYSICAL CHARACTERISTICS OF THE STUDY AREA

TABLE 4.1 (continued)
EXAMPLE TS REPORT OUTLINE
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

SURFACE FEATURES

Topography and Surface Water Hydrology

REGIONAL GEOLOGY AND HYDROGEOLOGY

SITE GEOLOGY AND HYDROGEOLOGY

Lithology and Stratigraphic Relationships

Ground Water Hydraulics

Ground Water Use

CLIMATOLOGICAL CHARACTERISTICS

NATURE AND EXTENT OF CONTAMINATION AND SOIL AND GROUND WATER GEOCHEMISTRY

SOIL CHEMISTRY

Residual-Phase Contamination

Total Organic Carbon

GROUND WATER CHEMISTRY

Dissolved-Phase Contamination

Ground Water Geochemistry

Expressed Assimilative Capacity

GROUND WATER MODEL

GENERAL OVERVIEW AND MODEL DESCRIPTION

CONCEPTUAL MODEL DESIGN AND ASSUMPTIONS

INITIAL MODEL SETUP

Grid Design and Boundary Conditions

Ground Water Elevation and Gradient

BTEX Concentrations

Dissolved Oxygen

MODEL CALIBRATION

Water Table Calibration

BTEX Plume Calibration

TABLE 4.1 (continued)
EXAMPLE TS REPORT OUTLINE
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

TABLE 4.1 (continued)
EXAMPLE TS REPORT OUTLINE
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field and trip blanks; decontamination of all equipment that the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the USEPA mobile laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., ground water), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of 4°C.

All field sampling activities will be recorded in permanent ink in a bound, sequentially paginated field notebook. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate/replicate samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

Ground water samples collected from monitoring points or using modified CPT procedures should provide sufficient volume for some duplicate analyses. Refer to Table 3.1 and Appendix A for further details on volume requirements.

One rinseate sample will be collected for every 10 or fewer ground water samples collected from existing wells. Because disposable bailers may be used for this sampling

TABLE 5.1
QA/QC SAMPLING PROGRAM
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

QA/QC Sample Types	Frequency Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates[a]	10%	VOCs
Rinseate Blanks[b/]	10%	VOCs
Field Blanks[b/]	5%	VOCs
Trip Blanks	One per shipping cooler	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

[a/] Ground water and soil samples
[b/] Ground water samples

event, the rinseate sample will consist of a sample of distilled water poured into a bailer and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs only.

A field blank will be collected for every 20 or fewer ground water samples (from both ground water monitoring points and ground water monitoring wells) to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

Trip blanks will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blanks will be prepared by the

laboratory and will be transported inside the sample coolers. These samples will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

SECTION 6

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APPENDIX A

CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING REQUIREMENTS FOR SOIL AND GROUND WATER SAMPLES

TABLE A.1
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Volatile organics	Gas chromatography/ mass spectrometry method SW8240.	Handbood method	Data is used to determine the extent of chlorinated solvent and aromatic hydrocarbon contamination, contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon®-lined cap; cool to 4°C	Fixed-base
Soil	Dehydrogenase enzyme activity (optional)	Colorimetric RSKSOP-100	Reduction of added triphenyltetrazolium chloride by soil microbes is measured colorimetrically; analyze immediately	An indicator of the presence of soil microbes, which are necessary for bioremediation to occur	At the beginning of the project	Collect 100 g of soil in a glass container	Field
Soil	Aromatic hydrocarbons (benzene, toluene, ethyl-benzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil; the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base
Soil gas	Carbon dioxide content of soil gas	Nondispersive infrared instrument operating over the range of approximately 0.1–15 percent	Soil gas carbon dioxide may be produced by the degradation of petroleum hydrocarbons	Data used to understand the carbon dioxide concentration gradient with depth and to infer the biological degradation of petroleum contaminants	Each sampling round	N/A	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil gas	Oxygen content of soil gas	Electrochemical oxygen meter operating over the range of 0–25 percent of oxygen in the soil gas sample	The concentration of soil gas oxygen is often related to the amount of biological activity, such as the degradation of petroleum hydrocarbons; soil gas oxygen concentrations may decrease to the point where anaerobic pathways dominate	Data are used to understand the oxygen concentration gradient with depth and to determine the presence or absence of aerobic degradation processes	Each sampling round	N/A	Field
Soil gas	Methane content of soil gas	Total combustible hydrocarbon meter using a platinum catalyst with a carbon trap, and operating in the low parts per million volume (ppmv) range	Methane is a product of the anaerobic degradation of petroleum hydrocarbons	Soil gas methane can be used to locate contaminated soil and to determine the presence of anaerobic processes; see discussion of data use for methane in water	Each sampling round	N/A	Field
Soil gas	Fuel hydrocarbon vapor content of soil gas	Total combustible hydrocarbon meter operating over a wide ppmv range	Soil gas hydrocarbons indicate the presence of these contaminants in the soil column	Data used to understand the petroleum hydrocarbon concentration gradient with depth and to locate the most heavily contaminated soils	Each sampling round	N/A	Field
Water	Ferrous (Fe^{+2})	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ferrous (Fe^{+2})	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100mL of water in a glass conatainer	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Colect 100 mL of water in a glass conatiner	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl^- C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen *in situ*	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L	Phenolphtalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 100mL of water in glass container	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
WURTSMITH AFB, OSCODA, MICHIGAN

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	A2320, titrimetric; E310.2, colorimetric	Handbook method	Same as above	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	Nitrate (NO_3^{-1})	HACH method # 8039 for high range method # 8192 for low range	Colorimetric	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO_4^{-2})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH method # 8051	Colorimetric	Same as above	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Dissolved sulfide (S^{-2})	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
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WURTSMITH AFB, OSCODA, MICHIGAN

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ethane, ethene	RSKSOP-114 (cont'd)	Ethane and ethene are analyzed in addition to the other analytes only if chlorinated hydrocarbons are contaminants suspected of undergoing biological transformation	Ethane and ethene are products of the bio-transformation of chlorinated hydrocarbons under anaerobic conditions. The presence of these chemicals may indicate that anaerobic degradation is occurring			
Water	Carbon dioxide	HACH test kit model CA-23 or CHEMetrics Method 4500	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect 100 mL of water in a glass container	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
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Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling	One time per year or as required by regulations	Volatile hydrocarbons–collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons–collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
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Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base
Water	Volatile Organics	GS/MS method SW8240	Handbook method	Method of analysis for chlorinated solvents and aromatic hydrocarbons for evaluation of cometabolic degradation; measured for regulatory compliance when chlorinated solvents are known site contaminants	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Dissolved organic carbon (DOC) (optional)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	An indirect index of microbial activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
INTRINSIC REMEDIATION TS
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Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Temperature	E170.1	Field only	Well development	Each sampling round	N/A	Field
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

TABLE A.1 (Continued)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
SITES OT-41 AND SS-42
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NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to *Robert S. Kerr (Environmental Protection Agency Laboratory) Standard Operating Procedure*.
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.